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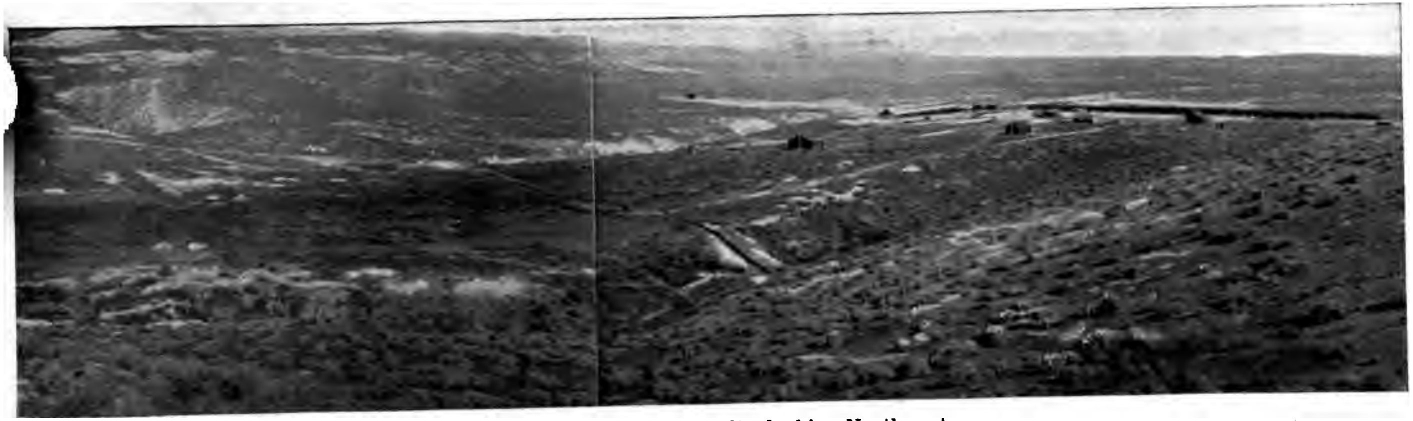
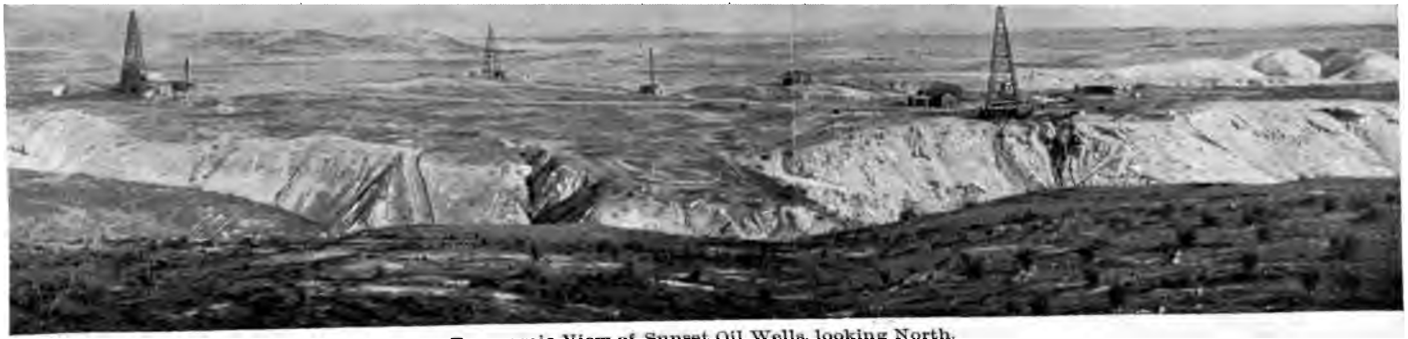
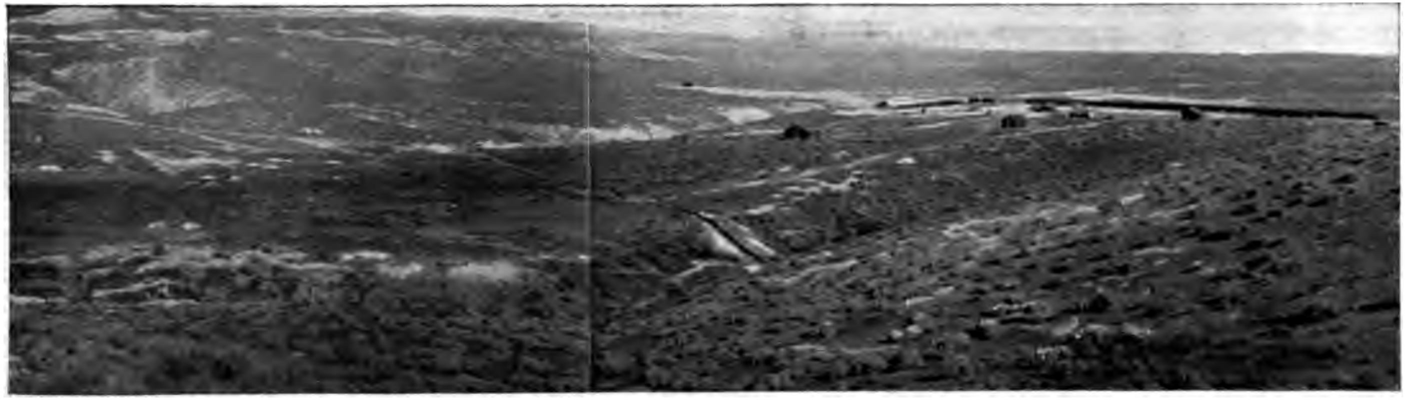


Panoramic View of Asphalto, looking Northwest.



Panoramic View of Sunset Oil Wells, looking North.



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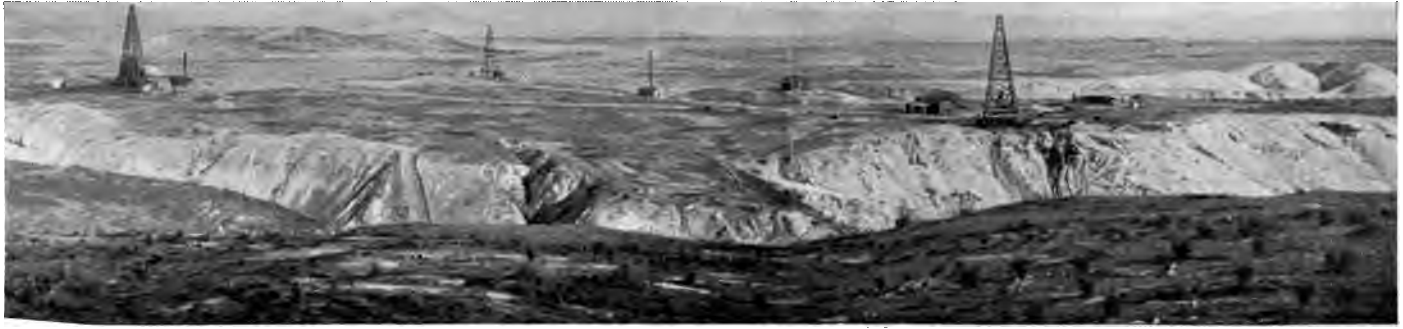

Panoramic View of Sunset Oil Wells, looking North.

RNIA STATE MINING BUREAU.

J. J. CRAWFORD, State Mineralogist.

N NO. 3. San Francisco, August, 1894.

THE

PETROLEUM YIELDING FORMATIONS

OF THE

TRAL VALLEY OF CALIFORNIA.

By W. L. WATTS, M.E.,
Assistant in the Field.

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California State Mining Bureau,
August 1, 1894.

J. Crawford, *Esq.*, *State Mineralogist:*

ar Sir: I have in the accompanying article correlated all the mation I have as yet obtained concerning the gas and oil yielding tions in the Central Valley of California and the neighboring ills. Appended thereto are the results of experiments made to mine the fuel value of the natural gas both at Sacramento and ton, and in certain localities situated in the upper portion of the oaquin Valley.

recounting experiments and stating results, I have used the metric m, except in the case of the brine analyses, wherein the results are in terms of grammes to the gallon. To do otherwise would in instances have necessitated the expression of results by both the ish and metric systems, and that would have added to the time the preparation of this article has consumed, and increased the nt of printed matter.

Yours respectfully,

W. L. WATTS,
Assistant in the Field.

THE GAS AND PETROLEUM YIELDING FORMATIONS OF THE CENTRAL VALLEY OF CALIFORNIA.

By W. L. Watts, Assistant in the Field.

As is well known, the Central Valley of California comprises the Sacramento and San Joaquin Valleys, which are bounded on the east by the Sierra Nevada and on the west by the Coast Range.

THE SACRAMENTO VALLEY.

It is on the tide-water lands at the southern base of the Potrero Hills in Solano County that natural gas is first encountered in the Sacramento Valley. When this locality was last visited by the writer, large quantities of gas were bubbling from several springs. These springs also yield copious flows of water and have washed out basins, one of which is more than 100 feet in diameter, and is said to be 30 feet deep at high tide. One of these springs was dry and gave off only a small amount of gas. It was said that this spring had been very active earlier in the year, and appearances indicated that such had been the case, for the spring had evidently brought up a quantity of light-colored sand, which smelled strongly of petroleum. Other springs were said to exist in the neighboring marsh. The range of these springs is from a northwesterly to a southeasterly direction, and it is quite likely that they mark a line of earthquake fracture. Inflammable gas is said to have been struck in a deep well near Goodyear Station, between Benicia and Suisun; and Dr. Dobbins, of Vacaville, states that while sinking a well about a quarter of a mile from that town, he penetrated a black shale, which smelled strongly of petroleum. This shale can be seen standing at a great angle in the bed of Ulattis Creek not far from Vacaville.

It does not appear that inflammable gas has been found in the valley lands of Yolo County; but in Colusa County natural gas is found in many places, both at the base of the foothills and in the foothills themselves. In this county, natural gas is generally associated with brine springs, as is the case at the head of Salt Creek, in the foothills west of the villages of Arbuckle and Williams. On the Stovall ranch, some 8 miles west of Williams, a well was bored in 1885 to the depth of 150 feet. In this well, which is now filled up, the water was salt; gas bubbled up freely through the water, and was readily ignited. The formation is:

Soil	30 feet.
Shale	30 feet.
Soft sandstone	90 feet.

A few miles west of this well the foothills are reached. The formation is shale and sandstone, which dip in a northerly direction at an angle of about 20°. Not far from where the Freshwater Creek enters the main valley, a 6-inch well was bored in 1864 or 1865 to a depth, as some say, of 300 feet, and as others say, of 900 feet. The casing is now nearly filled up with rubbish which has been dropped into it. A small stream of bitter-tasting brine still flows from the well, and inflammable gas rises through the water. A few yards north of this well, thin strata of shale and sandstone dip a little east of north, at an angle of about 70°. The barometer here showed an altitude of 160 feet. A mile or so farther west, on the Lake County road, near the Mountain House, a spring yielding petroleum is reported. At the McMichael ranch, on the Lake County road, a well was bored for oil many years ago, but it is filled up. On this ranch numerous thin strata of shale and sandstone are exposed. The strike is nearly north and south, and the dip is in an easterly direction at a great angle. The barometer here showed an altitude of about 300 feet. About one and a half miles southeast from McMichael's a second well was bored on the Stovall ranch, which still yields a small quantity of both gas and oil. Farther west the road crosses a divide, on the summit of which the barometer indicated an altitude of 1,200 feet; the formation dips in an easterly direction at a great angle.

As Bear Creek is reached, the stratified rocks are metamorphosed, the strike being west of north, and the dip northeasterly at an angle of about 70°. On this creek, at a short distance from the roadway, is the oil claim of J. P. Rathburn. Here the stratified rocks give place to serpentine with oil exuding from it, and forming small pools upon its surface. (See table of oil analyses at the end of this bulletin.) Between the roadway and Mr. Rathburn's claim, jaspery rocks, impure limestone, and sandstones traverse the creek. Farther up the stream a comparatively unaltered sandstone is exposed, which has a strike of west of north, and from it a heavy petroleum oozes in several places. In the creek near these oil springs gas can be seen rising through the water.

Also on Sulphur Creek there are both natural gas and petroleum, and on this creek fossiliferous limestone crops out, which smells strongly of petroleum. The fossils were principally *Rynchonella Whitneyi*. At the Elgin Mine, on this creek, gas issues from a hole about 3 feet deep, and the writer saw it burning with a flame about 3 feet in height. Immediately above the gas spring, between croppings of sandstone, is a decomposed shale, which emits a fetid odor and inflammable gas when disturbed.

At Sites' Station, close to the foothills in Colusa County, a well was bored in 1886 which yielded salt water and inflammable gas. The formation is stated to be as follows:

Adobe soil	28 feet.
Shale	45 feet.
Hard "slate"	265 feet.

The well-borers state that at a depth of 146 feet a thin vein of auriferous rock was passed through; that in this rock free gold could be seen, and that borings from it assayed at the rate of $360 a ton. Below a depth of 28 feet this well yielded salt water, and the saltness increased with the depth of the well. The salt water appeared to come from seams, which were about 6 feet apart. At a depth of about 130 feet inflammable gas was observed, and the quantity of gas increased as the well was bored deeper. At the completion of this well the salt water stood within 4 feet of the surface.

At the Petersen ranch, about three miles north of Sites, there are several brine springs from which inflammable gas issues. These salt springs are situated in a small valley leading into Antelope Valley at the edge of the foothills, and at an altitude of about 200 feet. During the winter the extremity of the small subsidiary valley is occupied by a shallow lake, which has an area of about 25 acres. This lake dries up during the summer, leaving a deposit of sand and loam washed and blown from the adjacent hills. This accumulation, which is mixed with much salt, lies to the depth of several feet on a bed of bluish clay. From any boring penetrating this clay to a depth of 6 or 7 feet, salt water and inflammable gas are obtained. About 15 feet below the surface a sandy stratum is encountered, which yields a still larger amount of brine and gas than is obtained in shallower wells.

The geological formation of this locality is very interesting. On the northern side of the lake a friable sandstone, streaked with calcite, is exposed, which dips in a southwesterly direction at a great angle. On the southern and opposite side of the lake a similar sandstone is to be seen, but it dips to the east of north at an angle of about 55°. This locality exhibits a similar geological structure to that seen at Tuscan Springs, in Tehama County.

About half a mile east of the salt springs the formation is fossiliferous, and several Cretaceous fossils were obtained in the second tier of hills from the Sacramento Valley. These fossils were submitted to Dr. J. G. Cooper, who determined them as follows:

Trigonia tryoniana, Gabb	Cretaceous.
Actæonina Californica, Gabb	Cretaceous.
Dentalium stramineum, Gabb	Cretaceous B.
Ammonites batesi, Trask	Cretaceous.
Cucullæa truncata, Gabb	Cretaceous.
Lunatia avellana, Gabb	Cretaceous.
Arca breweriana, Gabb	Cretaceous.

The formation from which the fossils were obtained consists of shale and sandstone with thin strata of fossiliferous limestone. The strike is west of north, and the dip northeasterly, at an angle of about 50°. It appears, therefore, that these fossils are of the same age as the fossils found at Tuscan Springs in Tehama County; namely, Cretaceous and of the Chico group.

Passing northward into Glenn County, natural gas appears to have been observed only at one place. The formation yielding the brine, however, seems to skirt the foothills; for it has been struck in wells about 17 miles west of Willows. There are also said to be brine springs about 3 miles west of Elk Creek. If wells were bored in the formation yielding the brine, the probability is that natural gas would be found. The only place in this county where natural gas is reported to have been observed, is at the Rideout ranch, near Norman. On this ranch two wells were bored, each to the depth of 940 feet. The formation penetrated is alternate strata of sand and clay. A small amount of inflammable gas is said to have been observed in these wells when they were first bored. In 1892, a small stream of fresh water was flowing from one of these wells which is about two miles north of Norman, but the gas had either ceased, or had been "cased" off.

In Tehama County, inflammable gas has been observed in several wells which have been dug in the western portion of the county. In a well about half a mile north from Stony Creek Buttes, the formation is stated to be as follows:

Soil	5 feet.
Cement gravel (this stratum yields inflammable gas)	30 feet.
Blue clay	43 feet.

On the Stark ranch, in Sec. 8, T. 26 N., R. 4 W., M. D. M., about 7 miles southwest from Red Bluff, inflammable gas was struck in black clay at a depth of 75 feet. The gas prevented work, and was ignited by the workmen; the well was then abandoned. A similar experience was had in a well dug to the depth of about 60 feet in Sec. 16, T. 28 N., R. 4 W., M. D. M., on what is known as the Oakwood Colony Tract, 11 miles northwest from Red Bluff.

In the autumn of 1891, a well was dug on the Thurman ranch, about 9 miles northwest from Orland, and at a depth of 25 or 30 feet inflammable gas was encountered. This was ignited by a workman while lighting his pipe, and resulted in his receiving severe burns.

Crossing the valley to Tuscan Springs natural gas is again found. At Tuscan Springs, as is well known, inflammable gas issues together with thermal water from the upturned edges of Cretaceous strata, and at one time the gas was used for heating the baths established there. These springs have so often been described that it is sufficient to say the Cretaceous rocks here present an anticlinal, and the water and gas escape from fractures upon its axis. The geological formation at these springs, and at the Petersen ranch, near Sites, in Colusa County, presents great similarity. It is only reasonable to conclude that the gas is of Cretaceous origin.

Research amongst the wells of the Sacramento Valley brought to light an interesting phenomenon. In portions of Tehama County known as the Chaparral Hills and the Adobe Hills, what appear to be currents of air are found, sometimes escaping from, and at other times being drawn into, strata of sand or porous clay; and the direction of these air currents appears to depend on the condition of the atmosphere. (See our XIth report, page 478.)

The only inflammable gas in Butte County, so far as heard from, was on the ranch of M. Wick, about 6 miles northwest of Oroville, where it was struck in boring a well. The gas was ignited and is said to have blazed up for several feet above a 5-inch casing. The formation penetrated is stated to be:

Loam	2 feet.
Cement gravel	6 feet.
Yellow clay	16 feet.
Soft sandstone	8 feet.

In Yuba County inflammable gas was struck in a well bored to the depth of 218 feet at the Buckeye Mill, and in a well 180 feet deep at the waterworks. In boring the well at the Buckeye Mill, the formation was found to be strata of clay, sand, and gravel. Between the depths of 80 and 140 feet much partially decomposed wood was brought up by the auger, and strata of clay were penetrated, which showed the impressions of numerous shells. Gas was struck between the depths of 212 and 220 feet.

At the waterworks and at the Buckeye Mill the gas collects in the air-chamber of the pump, and is frequently ignited from a burner attached to the air-chamber for that purpose. It burns with a fairly luminous flame, but it contains some carbonic di-oxide.

Crossing the Feather River to Sutter County, we find that inflammable gas has been struck in several wells which have been bored to the south of the court-house in Yuba City. These wells are less than 60 feet ep. At one place inflammable gas was noticed issuing from the ground during wet weather. In some of the wells in Yuba City where natural gas was observed, the formation is as follows:

Soil	20 feet.
Quicksand	6 to 20 feet.
Blue clay	40 feet.
Blackish sand, with gas.	

At one well, which is 60 feet deep, a cap was fitted to the top of the casing with a nozzle half an inch in diameter, and the gas was burned therefrom, producing a flame more than 2 feet in height.

In February, 1864, a shaft was sunk to prospect for coal on the ranch of Eli Davis, at the foot of the South Butte, about 6 miles from Sutter City. The shaft was about 40 feet deep, and from the bottom of it a tunnel was run about 40 feet in the sandstone. In this sandstone inflammable gas was struck, which being ignited, resulted in an explosion, to the injury of the miners. The gas escaped from seams in the sandstone, and a roaring sound attributed to it could be heard at the mouth of the shaft. Subsequently another shaft was sunk a short distance from the old one. This second shaft is about 4 feet square and 30 feet deep, and two wells have been bored therein. The first well, which was sunk in the 60s, is 60 feet in depth; it still yields inflammable gas, which smells of petroleum, and burns with a luminous flame, fluctuating from a few inches to about 2 feet, from the top of a 6-inch casing. The formation penetrated by the 4-foot shaft is a somewhat bituminous shale to a depth of 28 feet; in the shale two little seams of water were struck. The boring at the bottom of the shaft was made for 32 feet in sandstone. Below the shale the borings were dry, and it is said that the flow of gas was so strong that it blew the borings out of the drill-hole. A drill and chain are said to have been lost during the boring of this well. In 1891 another well was sunk in the 4-foot shaft. This well is about 2 feet from the first one, and although it was bored to a depth of 130 feet, it yielded but little gas.

As is well known, the Marysville Buttes are principally composed of volcanic rocks, but as the writer has nowhere seen a description of the very interesting sedimentary formations on the flanks of the Buttes, he considers that the following note may be of interest:

Leaving Sutter City by the South Pass road leading to Colusa, a valley is entered, formed by spurs from the Marysville Buttes, and these spurs are covered with micaceous trachytic lava. At the base of the Buttes the sedimentary rocks are exposed. At the Newcomb ranch the creek by the roadside has cut into the bank, showing a bedrock of sandstone and light-colored shale, the strike being north of west. The Buttes are a cluster of volcanic eminences which rise to the height of from 1,827, or thereabouts, to 2,178 feet. On the western portion is a ridge with four principal summits, and on the east are three more isolated peaks, while several spurs and hills of lesser elevation surround the main group of mountains. In ascending the most southerly peak from the Moody ranch patches of light-colored sand, toward the base of the mountain, mark the sedimentary formations and the coal measures. A few fragments of fossiliferous rock, showing Cretaceous fossils, may be found on a portion of the slope. The upper part of the mountain is composed entirely of micaceous trachytic lava, which becomes more crystalline toward the summit. The best exposure of sedimentary rocks was seen at the base of the West Butte, about a mile from the village of that name. On the west side of the Buttes the sedimentary strata are cut through by ravines nearly at right angles to the strike of the formation. In one gulch the evidence of successive displacements can be observed. Near the mouth of the gulch strata of sand and gravel dip in a southwesterly direction at an angle of about 15°. A few yards higher up the creek the formation changes to whitish sand, iron-stained in places, the dip being northwesterly; and in two or three places the dip of the whitish sands is variable, changing from northwest to southwest. The white, sandy formation rests upon Cretaceous shales and clayey sandstones, which dip in a southwesterly direction at an angle of about 70°. The Cretaceous shales are traversed by thin strata of fossiliferous limestone. From the shales and the limestone strata several fossils were obtained by digging. These were submitted to Dr. J. G. Cooper for examination, and he classed them as follows:

Leda gabbi, Con.	Cretaceous B.
Lunatia horni, Gabb	Cretaceous B.
Olivella mathewsoni, Gabb	Cretaceous B.
Nucula solitaria, Gabb	Cretaceous.
Nassa cretacea, Gabb	Cretaceous.
Turritella uvasana, Gabb	Cretaceous.
Turritella chicoensis, Gabb	Cretaceous.
Meretrix horni, Gabb	Cretaceous B.
Galerus excentricus, Gabb	Cretaceous.
Cardita veneriformis, Gabb	Cretaceous.
Ostrea idriaensis, Gabb	Cretaceous B.
Corbula parilis, var?, Gabb	Cretaceous B.
Mysia polita, Gabb	Cretaceous B.
Modiola cylindrica, Gabb	Cretaceous.
Cardita planicosta, Lam.	Cretaceous B.
Arca horni, Gabb	Cretaceous B.
Cardium translucidum, Gabb	Cretaceous.
Dentalium	Cretaceous.
Morio tuberculatus, Gabb	Cretaceous B.
Architectonica horni, Gabb	Cretaceous B.
Cucullea	Cretaceous.

Several new species were also obtained from this locality.

The only natural gas observed in the valley lands or foothills of Placer County, was on the Blair placer mining property, where boring showed the following formation:

Auriferous cement gravel	18 feet.
Water.	
White volcanic ash and fragments of quartz and white sand	20 feet.
Coal	21 inches.
White volcanic ashes	15 feet.
Coal	6 inches.
Alternate strata of white ashes and gravel with thin layers of coal, nine altogether, to a depth of	90 feet.

One hundred yards south from this boring a similar formation was observed to a depth of 80 feet; the water rose to within 6 feet of the top of the casing, and gas bubbled through it. After an explosion of giant powder in the well, a flame, extending about 18 inches above the top of the casing, burned for fifteen minutes.

About twenty years ago two wells were bored on the Haggin ranch, on the Norris grant, about 9 miles northeast from the city of Sacramento. One of these was bored to a depth of 2,250 feet, and the other to a depth of 1,600 feet. These wells yielded salt water by pumping, and a small quantity of inflammable gas arose from the deepest.

In 1889–90 a company was formed at Sacramento under the name of the Natural Gas and Water Company, to sink a well for artesian water gas in the southwestern portion of the city. This company bored a . to the depth of 876 feet. The formation penetrated is alternate ta of clay, gravel, cement, and quicksand; the lower portion of the ıation being a hard, porous, sandy cement. Flowing water was ck in coarse sand at a depth of 281 feet, and a slight showing of gas observed at 392 feet. The flow of water and gas increased with the th, but at 866 feet operations were suspended, owing to an accident he casing. It is roughly estimated that the yield of gas from this . exceeded 2,000 feet in twenty-four hours.

ı March, 1892, a new well, which we will call the Sacramento Gas .l No. 2, was commenced about 150 feet eastward from the old gas .. In May, 1893, Gas Well No. 2 had been bored to the depth of feet; but the boring was suspended, owing to difficulty resulting ı a sand-pump becoming fast at the bottom of the casing. The .-borers state that many of the strata penetrated by this well were hard and required reaming; also, that the greatest trouble resulted ı the sand "packing" around the casing when it was standing on a l stratum during the process of reaming.

he well No. 2 is cased with 14-inch casing for the first 505 feet, and ı 12-inch casing from that depth to the bottom, 965 feet. It is stated the casing was put down in joints 4 feet in length, and that each *t was coated internally and externally with asphaltum.*

he value of this latter precaution is very great, since the asphaltum ects the iron from any acid which might accompany the inflam-)le gas, or which the water flowing from the well might hold in tion. The following samples of strata penetrated are preserved in les and labeled with a statement as to the depth at which each ple was obtained:

Depth of Well.	Record of New Well No. 2, as Shown by Contents of Bottles.
8 ft.	Quartzcse pebbles, with water-worn fragments of wood, at a depth of 87 feet.
eet.	Light-colored, porous, sandy clay.
eet.	Fine grayish sand.
eet.	Grayish sandy clay.
eet.	Grayish sand (rather coarse).
eet.	Fine micaceous cemented gray sand.
eet.	Coarse sand, with fragments of cemented fine sand.
eet.	Light-colored clay.
eet.	Micaceous sand, with fragments of cemented sand.
eet.	Fine micaceous sand, the particles being somewhat agglutinated, but friable.
eet.	Cemented fine sand, resembling soft, friable, micaceous sandstone.
eet.	Light brown, porous sandy clay, with infiltrations of white clayey matter.
eet.	Soft agglutinated fine sand; friable.
eet.	Fine sand with small pebbles.
eet.	Light-colored clay.
eet.	Fine micaceous sand.
eet.	Light-colored, sandy clay.
eet.	Very fine sand cemented with clayey matter; indurated.
212 feet.	Fine sand, small pebbles, and lumps of cemented sand.
220 feet.	Fine, sandy, light-colored clay.
232 feet.	Micaceous sand and fragments of light-colored cemented sand.
238 feet.	Soft, cemented, fine sand.
240 feet.	Sand, with fragments of wood.
245 feet.	Light-colored, sandy clay.
248 feet.	Light-colored, cemented sand, with white clayey infiltrations.
261 feet.	Grayish sand.
265 feet.	Light-colored clay.
266 feet.	Coarse sand.
274 feet.	Porous, cemented, light-colored sand.
280 feet.	Friable cemented sand.
287 feet.	Fine sand.
307 feet.	Whitish clay.
310 feet.	Light-colored clay.
318 feet.	Fine sand and fragments of cemented sand.
328 feet.	Light-colored, sandy clay.
329 feet.	Light-colored, sandy clay.
330 feet.	Agglutinated sand, friable.
332 feet.	Whitish clay.
334 feet.	Fine micaceous sand; (first flowing water).
352 feet.	Porous, clayey sand.
356 feet.	Fine sand.
376 feet.	Light-colored·clay.
394 feet.	Coarse sand and small pebbles, with flowing water.
400 feet.	Porous, light-colored, sandy clay.

Depth of Well.	Record of New Well No. 2, as Shown by Contents of Bottles.
413 feet.	Hard, light-colored clay.
415 feet.	Cemented, fine sand.
425 feet.	Whitish clay.
430 feet.	Micaceous sand, with white quartz and quartzose pebbles at 427 ft.
431 feet.	Whitish, sandy clay.
434 feet.	Porous, sandy clay.
437 feet.	Agglutinated fine sand, friable.
450 feet.	Porous, clayey sand.
465 feet.	Porous cemented sand, very hard.
470 feet.	Very fine, cemented, micaceous sand.
485 feet.	Micaceous sandstone.
487 feet.	Whitish clay.
509 feet.	Micaceous, cemented sand.
521 feet.	Loose sand ; strong flow of water.
528 feet.	Sandy clay, hard as sandstone.
538 feet.	Cemented, micaceous sand.
545 feet.	Light-colored clay.
569 feet.	Coarse sand.
570 feet.	Quartzose pebbles.
575 feet.	Light-colored clay.
578 feet.	Gray, porous sand rock.
595 feet.	Light-colored clay.
597 feet.	Agglutinated, fine sand.
600 feet.	Clayey sand.
608 feet.	Micaceous sand.
612 feet.	Soft, clayey, fine sand.
616 feet.	Fine micaceous sand.
622 feet.	Light-colored clay.
623 feet.	Fine micaceous sand.
625 feet.	Fine cemented sand.
632 feet.	Porous cemented sand.
640 feet.	Gray cemented sand.
642 feet.	Fine micaceous sand.
650 feet.	Cemented sand.
651 feet.	Light brown clay, with white clayey infiltrations.
668 feet.	Porous clayey sand.
674 feet.	Loose sand.
683 feet.	Light-colored clay.
688 feet.	Loose sand.
690 feet.	Brown clay.
692 feet.	Porous sandy clay.
693 feet.	Loose sand.
695 feet.	Brownish clay.
700 feet.	Porous sandy clay.
715 feet.	Brownish clay.
718 feet.	Loose sand; at this depth there was an increased flow of water, accompanied by gas.
720 feet.	Sand, cemented with clay.
723 feet.	Agglutinated, sharp sand.
727 feet.	Loose sand.
732 feet.	Light-colored clay.
736 feet.	Cemented sand, friable.
738 feet.	Light-colored indurated clay.
739 feet.	Cemented sand.
801 feet.	Brownish, sandy clay.
803 feet.	Loose sand.
804 feet.	Brownish clay, with white clayey [infiltrations.
812 feet.	Light-colored indurated clay.
814 feet.	Cemented grayish sand.
820 feet.	Loose sand.

Between this depth and that of 872 feet the well-borers state that strata of hard sandstone were passed through; that at the depth of from 840 to 845 feet a stratum of very porous sandstone yielded more water and gas; and that blue clay was penetrated between the depth of 860 and 865 feet. The sample which was marked as representing the formation at a depth of 900 feet, contained a light-colored and somewhat calcareous clay.

In reviewing the record of the strata penetrated by this well and the samples from it, which have been preserved, the fact must be borne in mind that when material is first taken from the well during the process of boring, it frequently looks very different from what it does when dried and kept for some time. Nearly all the light-colored clays look blue when first brought up from the well, and the micaceous sands look black, frequently becoming bluish when dry. All the loose micaceous sand is quicksand, and well-borers state that it "runs badly"; *i. e.*, it runs into the boring and casing, and is apt to cover the tools.

The term agglutinated sand is used for that whose grains adhere to one another without any visible cementing material; and the term cemented sand, when the cementing material can be seen.

Many of the samples, when dried, resemble soft, clayey sandstones. The physical appearance of some of them resembles a very recent formation overlying the Ione coal measures cropping out a few miles eastward from Clements, in San Joaquin County.

In a general way, it is obvious that many of the strata penetrated by he gas wells at Sacramento are harder than those encountered at similar epths at Stockton.

The old gas well at Sacramento is about 150 feet from the Gas Well No. 2, and it flows about 18 miner's inches of water. On May 16, 1893, the temperature of this water was 69.5° Fahr. Gas Well No. 2 also yields a copious stream of water. A determination of the temperature of the water in this well, which was made at the same time as that of the old well, was 66.74° Fahr.

The temperature of the water in these wells is said to have been higher when it was previously estimated. It is quite probable that water from he melting snows of the Sierra may cool these subterranean waters uring the early summer, as it does the water in the river and streams n the eastern side of the Central Valley of California.

An estimation of the fuel value of the gas from the old gas well at acramento will be found at the conclusion of this bulletin. As the gas rom Well No. 2 was not collected under a receiver, its fuel value was ot estimated. The gas from both wells, when passed through lime ater for a few minutes, showed the presence of a small amount of caronic di-oxide.

ENERAL REMARKS ON NATURAL GAS IN THE SACRAMENTO VALLEY AND NEIGHBORING FOOTHILLS.

The instances have now been traced in which inflammable gas has hitherto been observed in the Sacramento Valley. The larger number of places where the gas was examined, were springs or shallow wells in the Cretaceous formations on both sides of the valley, and were little more than "gas prospects." The only deep wells penetrating the filling of the valley were found at the Haggin ranch, at Sacramento, and near Norman, in Glenn County. At the Haggin ranch, 9 miles north of Sacramento, natural gas and salt water were obtained; and it is noted that the salt water and gas were found together in Cretaceous formations in other places on the sides of the valley. At Sacramento, natural gas was observed at a depth of 392 feet; at the Rideout ranch, in Glenn County, the filling of the valley was penetrated 940 feet, and only a small amount of gas was observed, but this has now ceased. The well at the Blair placer mining property penetrates a late Tertiary formation.

These investigations warrant the conclusion that the natural gas in the Sacramento Valley is principally of Cretaceous origin, although any organic remains that have been subjected to the necessary chemical change beneath the clayey strata of the valley have contributed to the gas stored in adjacent porous formations. There is no doubt that the greater portion of the gas found in the alluvial formations in the Sacramento Valley has escaped from fissures in the older rocks; and that these fissures have been formed, not only by the ancient disturbances which culminated in the formation of the Marysville Buttes, but by earthquakes of the present era.

Comparing the traces of gas in the wells at the Rideout ranch, in Glenn County, with the amount of gas yielded by the wells bored at Sacramento, it might be argued that the Quaternary strata contain more gas in the lower than in the upper portions of the valley, but the results obtained by wells so far apart are insufficient for generalization. Moreover, the water resting on the gas-yielding formations at the Rideout well, in Glenn County, is probably much deeper than in the well at Sacramento.

From the foregoing it appears that the natural gas in the Sacramento Valley occurs under two conditions: First, when it issues from upturned edges of Cretaceous rocks on the sides of the valley, and from shallow wells penetrating that formation; secondly, when it escapes from wells penetrating the porous and more recent formations which fill the trough of the valley.

These researches in the Sacramento Valley and neighboring foothills lead to the conclusion that the gas-bearing formations are distributed through the rocks of the Cretaceous system. At Sulphur Creek gas and petroleum are found associated with rocks of the Knoxville series. At Sites and Tuscan Springs gas and salt water are found in rocks of the Chico group, and the fossils collected around Marysville Buttes, where gas is found, are referred by Dr. Cooper to the Chico Tejon or probably Eocene period.

There are five things which are all-important to consider in geological investigations with reference to natural gas: First, the lateral extent of the gas-bearing formations; second, the thickness of these formations; third, the porosity of the rocks, with a view of approximating their gas-holding capacity; fourth, the pressure under which the gas exists; and fifth, the character of the strata overlying the gas-holding rock; for unless the strata overlying the gas-holding rocks are of such a nature as to restrain the gas beneath them, a profitable gas field can never exist.

Investigation warrants the belief that the Cretaceous formations extend all through the Sacramento Valley, coming to the surface in the foothills and underlying the filling in the central portion of the valley. It is not known that the thickness of the Cretaceous formation in the Sacramento Valley has ever been estimated, but there is reason to believe that the Cretaceous rocks are thicker on the eastern slope of the Coast Range than on the western slope of the Sierra. There is also every reason to believe that many of the Cretaceous strata are sufficiently porous to afford good storage room for gas.

The question of the pressure under which the gas exists is an important one, but unfortunately it is a subject on which we have the least evidence; in the first place, because there are so few gas wells in the Sacramento Valley; in the second place, because the few that exist are full of water.

Of course, any gas that finds its way into the casing of a well, in excess of that which can be held in solution by the water, will come to the surface by its specific gravity; and in a flowing well films of gas are no doubt dragged by the water from the porous strata in which the gas is held.

If a well is only 330 feet deep, the pressure of the gas in the strata at the bottom of the well would have to exceed that of eleven atmospheres; that is, it must be more than 165 pounds to the square inch before the gas could escape. We have already seen that when dry gas was struck in the sandstone at Marysville Buttes, its pressure is said to have been sufficient to blow the borings out of the drill-hole; and it is possible that if the water could be excluded from wells in other portions of the valley, equally strong flows of gas might be obtained.

With regard to the character of the strata overlying the gas-holding rocks, we have abundant evidence. Throughout both the Sacramento and the San Joaquin Valleys borings made to obtain water penetrate sheets of clay, which appear to extend throughout the valley lands, and to overlie the gas-holding formations.

It would be a very interesting experiment to make a deep boring in a well-chosen spot in the Sacramento Valley, and to shut off the water by screw casings from the upper portion of the well, or if that could not be done, to exhaust the water by pumping. We should then know something definite about the pressure of the gas; and appearances certainly indicate that in some places sufficient gas might be obtained to be of practical value if it could be used on the spot.

In the more recent formations, in the central portions of the valley, where flowing water might be encountered, the task of shutting off the water would be difficult, and experiment alone could determine whether it is possible to exclude the water without shutting off the gas. Such is the record, up to date, of natural gas and petroleum in the Sacramento Valley.

NATURAL GAS IN THE SAN JOAQUIN VALLEY.

The Stockton Gas Wells.—In Stockton and vicinity there are more than twenty wells which yield natural gas in sufficient quantities to be of practical value. Indeed, for the last five years it has been an established fact that at Stockton, by boring to the depth of something less than 2,500 feet, sufficient gas can be obtained to light and materially reduce the fuel bill of a large factory, or to supply a group of families with light and fuel. The following record of strata penetrated by one well bored at the Stockton court-house, and by another which was sunk at the Jackson baths, gives an idea of the formation underlying the city of Stockton; and to a certain extent shows the nature of the strata holding the gas, and of the sheets of clay beneath which the gas is stored.

The Court-house Well.—This well, commenced in February, 1890, as mentioned in our Xth Report, was completed in December of the same year. In boring this well, after penetrating soil, hardpan, and clay to a depth of 60 feet, a stratum of blue clay was met, and from that on blue clay alternated with thin strata of sand until a depth of 220 feet was reached. At this depth a stratum of gravel more than 30 feet in thickness was encountered, the pebbles composing which varied from the size of marbles to that of a man's fist. Beneath this gravel, strata of clay, cement, and sand alternated to a depth of 900 feet, and then 30 feet of coarse sand was passed through. This sand yielded a large flow of good water. Beneath this sand the following strata were observed:

Character of Strata.	Depth at which the Strata were Observed to Change.
Coarse sand	to 930 feet.
Dark-colored clay	to 970 feet.
White marl, principally lime	to 990 feet.
Fine grayish quicksand	to 1,040 feet.
Coarse sand	to 1,070 feet.
Bituminous shale or clay (gas)	to 1,100 feet.
Soft, grayish sandstone	to 1,125 feet.
Grayish clay, full of holes, some of which were filled with white clayey matter	to 1,160 feet.
Coarse sand	to 1,200 feet.
Gray, ferruginous, sandy clay	to 1,230 feet.
Quicksand	to 1,280 feet.
Very soft, friable sandstone, with gas	to 1,300 feet.
Grayish, sandy clay, with infiltrations of white clayey matter, very hard	to 1,325 feet.
Light-colored, sandy cement	to 1,350 feet.

Character of Strata.	Depth at which the Strata were Observed to Change.
Sand	to 1,370 feet.
Clay, with little quartz pebbles	to 1,410 feet.
Sandy cement, with gas	to 1,450 feet.
Cement, more clayey	to 1,490 feet.
Coarse sand	to 1,530 feet.
Soft, clayey sandstone	to 1,560 feet.
Clayey sandstone, harder (gas)	to 1,600 feet.
Light-colored, friable sandstone	to 1,630 feet.
Light-colored, friable sandstone, but more clayey (gas)	to 1,660 feet.
Cement gravel (gas)	to 1,700 feet.
Indurated clay (gas)	to 1,800 feet.
Clean, soft, friable sandstone (gas)	to 1,870 feet.
Sample omitted from those sent to the Bureau	to 1,890 feet.
Coarse sand (gas)	to 1,917 feet.

The principal gas-yielding strata were encountered, and the casing perforated, at the following depths: 1,100 feet, 1,300 feet, 1,450 feet, 1,600 feet, 1,660 feet, 1,700 feet, 1,740 feet, 1,800 feet, 1,900 feet. This well is 12 inches in diameter at the top; at a depth of 670 feet it is reduced to 10 inches, and at 1,100 feet to 8 inches. The flow at the completion of the well is said to have been about 30,000 cubic feet of gas every twenty-four hours, and a large stream of water. The record of this well is especially interesting, from the fact that the method of boring allowed samples of the various strata to be brought up in masses, which gave a much better idea of the character of the formations penetrated than methods which pulverize the material before it is brought to the surface. Moreover, samples were preserved and forwarded to the Mining Bureau for examination. The most interesting stratum was the bituminous shale or clay which was struck at a depth of 1,070 feet, and the calcareous stratum which was penetrated between the depths of 970 and 990 feet. The bituminous sample presented no organic structure under the microscope, but some air-dried fragments examined showed the following composition:

Water	0.40 per cent.
Volatile hydrocarbons	55.03 per cent.
Fixed carbon	16.10 per cent.
Ash	28.46 per cent.
	99.99 per cent.

A very small portion of the mass was soluble in carbon di-sulphide. Of course it is only natural that dried samples when examined in the laboratory should seem much firmer than when first brought up wet from the well. Some of the strata penetrated by the Stockton gas wells, besides the actual sands and clays, are of a fine, loamy nature, varying from sandy to clayey; and resemble the Loess of the Mississippi Valley, except that the said Loess is usually buff-colored or of a reddish cast, while the material brought up from the wells at Stockton is usually of a bluish color. No doubt the reason of this is that the iron contained in the material from the gas wells at Stockton is in the ferrous condition, while that of the Loess in the Mississippi Valley is principally in the ferric, *i. e.*, the more highly oxygenized compound.

The peculiar bluish sand which is frequently brought up during the process of boring deep wells in the Central Valley of California is similar in appearance to the bluish sand composing some of the lower foothills of the San Joaquin Valley, as hereinafter described. Other samples brought up by the sand-pump from the gas wells mentioned resemble the friable sandy formations of the Kern River, which perhaps we may tentatively refer to the Pliocene group. But it is not well to place too much reliance on the comparative lithological structure of sedimentary rocks; for the physical appearance of the newer derivative formations frequently resembles that of the older sedimentary rocks from which they are formed.

Jackson Well No. 1.—This well, as mentioned in our IXth Report, was commenced in 1890. The casing has a diameter of 12 inches at the top, and 9¾ at the bottom; the depth of the well is 1,700 feet. The principal flows of gas and water were struck at the following depths: 746 feet (a small flow), 896 feet, 1,180 feet, 1,270 feet, 1,312 feet, 1,350 feet, 1,460 feet, 1,508 feet, 1,654 feet, 1,700 feet. The total yield of gas from this well is estimated at about 70,000 cubic feet in twenty-four hours. The water is used in a swimming-bath which has been built by Mr. Jackson at his wells.

Record of Strata Penetrated below a Depth of 880 Feet.

Coarse sand, with good flow of water and gas	880 feet.
Cement, porous in places, increased flow of water and gas	896 feet.
Cement gravel	914 feet.
Coarse sand	934 feet.
Hard blue cement	964 feet.
Quicksand	980 feet.
Blue clay cement	1,000 feet.
Porous, sandy cement, with gas	1,030 feet.
Tough clay	1,138 feet.
Blue, shaly "joint-clay"	1,170 feet.
Sand, with flow of water and gas	1,180 feet.
Cemented sand	1,230 feet.
Hard clayey cement	1,260 feet.
Porous sand, with flow of water and gas	1,270 feet.
Conglomerate	1,315 feet.
Unctuous clayey cement	1,334 feet.
Hard cement	1,340 feet.
Sand, with a large flow of water and gas	1,350 feet.
Cement	1,360 feet.
Hard, blue, slaty cement	1,426 feet.
Sand and gravel	1,430 feet.
Hard cement	1,445 feet.
Porous rock, with large flow of gas	1,460 feet.
Hard cement	1,500 feet.
Sand	1,508 feet.
Hard cement	1,530 feet.
Sand	1,535 feet.
Hard cement	1,578 feet.
Sandy clay	1,580 feet.
Porous, clayey sand and rock	1,600 feet.
Cement	1,630 feet.
Porous, sandy rock, yielding much gas	1,640 feet.
Loose sand	1,644 feet.
Cement	1,650 feet.
Sand, with large flow of gas and water	1,655 feet.

From this well, the incisor tooth of a horse, a much-worn carnivorous molar, and two fragments of jawbone, were brought up by the sand-pump from a depth of 1,058 feet.

Jackson Well No. 2.—This well, which was commenced in July, 1891, is situated about 110 feet south of the Jackson Well No. 1. The formation is similar to that of the first well. Gas was struck at a depth of 800 feet, and could be ignited in the casing. The water at that depth stood 4 feet from the top of the casing. As the well was bored deeper, it yielded an increased volume of gas, issuing from hard, porous strata; flowing water was struck at a depth of 1,350 feet. This well is said to be 1,400 feet in depth.

The Asylum Wells.—In March, 1892, the depth of Asylum Well No. 1, at the State Insane Asylum, was increased till it reached 1,750 feet. This resulted in a large increase in the flow of gas and water. In addition to the use of the gas in the laundry, the female department of the asylum is now entirely illuminated by it. The gas is also used as fuel for a ten horse-power engine, which pumps the sewage of the establishment, and the three horse-power engine, which pumps water for irrigation.

A new well was commenced at the asylum in 1892, the contract for boring being let to Haas & Jensen, of Stockton. In May, 1892, 600 feet had been successfully bored, and cased with 15-inch No. 12 iron, riveted pipe. A careful selection of specimens of the various strata passed through was being made under the supervision of Major Orr.

The St. Agnes Well No. 2.—This well was bored during 1891–2 at the St. Agnes College, and is about 75 feet south of Well No. 1, which was bored in 1889. This second well was bored to a depth of 1,720 feet, and the strata penetrated resemble those noted in the first well, a record of which is given in our Xth Report. The yield of the new well is more than 25,000 cubic feet of gas in twenty-four hours, and there is also a large flow of water. The well is cased with 10-inch double casing, No. 14 iron, to a depth of 900 feet; at this depth it is reduced to 8-inch, and this carried down to 1,240 feet, below which it is reduced to 6-inch. The 6-inch casing was cut at a depth of 1,100 feet, and pressed down to that depth. In the autumn of 1891 the St. Agnes Well No. 1 ceased to flow, and simultaneously the gas ceased to rise. A trench cutting the pipe of the well about 4 feet below the surface of the ground was then dug from the well to the bank of Mormon Slough. By this means flowing water was again obtained, and the well yielded gas as before.

The Stockton Natural Gas Company.—The officers of this company state that their new well has been completed, and the gas from it turned into the main. This company has built a new gasometer, which holds about 22,000 cubic feet of gas, thus doubling the gas-storing capacity of the plant belonging to the Stockton Natural Gas Company. The officers of the company report that the yield from their first well, *i. e.*, the Haas Well No. 1, is now about 80,000 cubic feet every twenty-four hours; and from their second well, which is said to be about 2,000 feet deep, about 43,000 cubic feet.

During the past year a great improvement has been made by the use of the "Welsh back burner" for household illumination by natural gas. With this burner the Stockton natural gas can be used directly from the meter without carburetting.

Mr. Haas, who bored the wells of the Stockton Natural Gas Company, stated that, while boring the second well, the gas expelled the water from the iron pipe forming the "boring-rod"; the gas was under such pressure that it burst the fire-hose attached to the escape pipe, which happened to be closed. Upon the bursting of the hose, the water again rose in the "boring-rod" and flowed therefrom. To obviate a recurrence of such an accident, Mr. Haas attached a vent-cock to the "boring-rod."

The Stockton Gas Light and Heat Company.—In the spring of 1894 work was still in progress at the well belonging to this company, and the well was said to be 1,400 feet deep. Tools had been lost in the well, but it is stated that they have been recovered.

The Citizens' Well.—This well, which was bored for the Citizens' Natural Gas Company in 1890, is said to yield 42,000 cubic feet of gas in twenty-four hours, and also a large flow of water. The well is 2,061 feet deep.

The Grant Street Well.—A well was commenced in February, 1892, by Jerome Haas at the corner of Fremont and Grant Streets, Stockton. When visited in May, 1892, this well had been bored to a depth of about 900 feet, and a small amount of gas was perceptible. Mr. Haas said that on April 28, 1892, when the casing was being forced down under a pressure of 100 pounds to the square inch, a slight earthquake occurred, and immediately thereafter it required a pressure of 800 pounds to the square inch to move the casing. The resistance gradually diminished until the former pressure of 100 pounds was sufficient to force the casing down.

The Central Well.—A well was commenced in 1891, on American Street and Miner Avenue, in Stockton, by a company organized under the name of the Central Natural Gas Company.

Other Gas Wells at and near Stockton.—A description of other gas-yielding wells, which have been sunk in Stockton and its immediate vicinity, can be found by referring to our VIIth, VIIIth, IXth, and Xth Reports.

Gas Well on Roberts Island.—The farthest west that natural gas has been obtained in San Joaquin County is on Roberts Island. On this island, at a point about 14 miles west of Stockton, a well, which yielded flowing water and gas, was sunk in 1883 by General Williams. This well is said to be 1,435 feet deep, and to be cased in the upper portion with 7-inch, and in the lower portion with 5-inch casing. The gas yielded by this well is said to have been sufficient to supply the ranch house with light and fuel. The water is saline, and it is said that the well was closed to prevent the water running on the land.

Natural Gas at Byron Springs.—Inflammable gas is found at Byron Springs, in the foothills of Contra Costa County. At this place the gas rises with thermal mineral water from springs and shallow borings. For a further description of these springs, see our VIIIth Report, p. 163.

At the Cutler Salmon Ranch, on the French Camp road, a well was bored in 1883 to the depth of 1,250 feet. At first a 7-inch pipe was put down to the depth of 1,250 feet, and inside of that a 4-inch pipe to the depth of 1,140 feet. The large pipe, which has no connection with the smaller one, yields a stream of fresh water and a small amount of inflammable gas. The 4-inch pipe yields brackish water and a larger amount of gas. The gas is used on the ranch for light and fuel.

In 1884 a well was bored to the depth of 1,404 feet at the *Pope Salmon Ranch,* about 9 miles southeast from Stockton. The well is cased with 7-inch pipe for the first 700 feet, and with 5-inch pipe from that depth to the bottom. The well yields sufficient gas for domestic purposes; the water is plentiful.

At Lathrop Junction an 8-inch well was bored in 1888 to a depth of 1,420 feet; this well yields flowing water and about 2,500 cubic feet of natural gas every twenty-four hours.

At the County Hospital, one mile east of Modesto, on the eastern side of the San Joaquin Valley, in Stanislaus County, a small quantity of gas rises from a well 1,070 feet deep. This well does not yield flowing water.

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In Merced County inflammable gas has been struck, together with fl ing water; and this is the case in more than one well a few miles southw of Merced City, at a depth of about 600 feet. The formation penetrate alternate strata of sand and clay. Thus, on the Oulds ranch, which 6 miles south of the county seat, the gas from a well 600 feet deep collected in a receiver 9 feet in height and 6 feet in diameter. Th receiver is filled in less than twenty-four hours, although much gas g to waste. The gas is used on this ranch for heating and lighting p poses, and gives great satisfaction. It is interesting to note, in this co nection, that there are wells between the county seat of Merced Coun and the San Joaquin River, of greater depth than the one on the Oul ranch, which yield flowing water but no gas.

At a point about 7 miles southeast of *White's Bridge, in Fres County*, a well was bored in 1892 which yielded inflammable gas an flowing mineral water. The formation penetrated is sand and cla flowing water was struck at a depth of 480 feet. Below a depth of 8 feet the sand became hard, "like sandstone"; at a depth of 1,050 feet became black, with some gas rising through the water; at 1,100 fee there was enough gas to furnish fuel for the engines running the drill Mineral water flowed from this well.

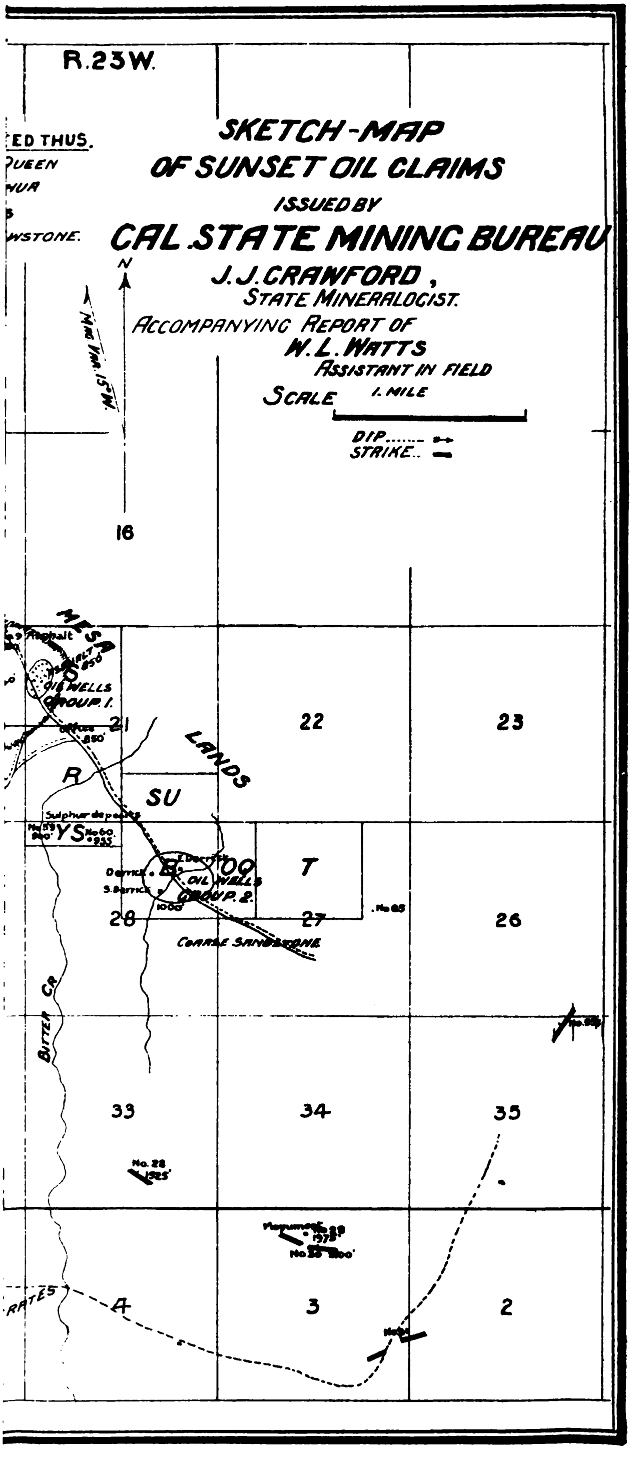
Near *Tulare Lake*, in Tulare County, several wells yield natural ga and flowing water. Thus, at the *Sevilla Colony*, 16 miles southwest o Pixley, there is a well 600 feet deep which yields sulphuretted water an a large quantity of gas. It is said that the yield of gas from this wel amounts to several thousand feet a day; that the gas burns with a clea flame, and that it has been running to waste for more than five years.

At the *Lambertson Ranch*, also near Lake Tulare, a well was bored i 1889 to a depth of 1,058 feet, which yields both flowing water an natural gas; the formation is alternate strata of sand and clay, wit much quicksand. The last 200 feet or more were nearly all through fin sand, which contains numerous shells. Some of these shells were exam ined by Dr. Cooper, who determined them to be *Amnicola turbiniformi* and *Sphærium dentatum.* The first named is a Pliocene, and the latter i a living fresh-water mollusk. From these shells it appears that the fillin of the valley to a depth of 1,058 feet is, geologically speaking, very recent

On the *Jacobs Ranch*, about 7 miles north of the Lambertson well, i July, 1889, a well was bored to the depth of 887 feet. Flowing wate was struck between the depths of 508 and 514 feet. The formation wa similar to that at the Lambertson well, but it contained less quicksand At the depth of 190 feet a flow of gas was encountered which forced th water out of the casing. As the casing was nearly filled with water a the time, the gas must have been under a pressure of more than seve atmospheres—that is, more than 105 pounds to the square inch. Th gas appeared to come from a stratum of blue sand about one foot i thickness, which was overlaid by a stratum of blue clay 50 feet thic Fifteen different flows of water were observed in this well, and an increas of the amount of gas was observed as each flow of water was struck.

GENERAL REMARKS ON OIL, GAS, AND ASPHALTUM IN KERN COUNTY.

Petroleum and gas bearing formations are found on both sides of th San Joaquin Valley in Kern County. At the Sunset Oil District and a Asphalto, on the western side of the valley, the petroleum and gas yield



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ing rocks are extensively exposed, and oil and asphaltum industries are carried on. At the Sunset Oil District there are also deposits of sulphur and gypsum. On the eastern side of the valley, oil, bituminous matter, and gas are found, notably in T. 29 S., R. 28 E., M. D. M., and T. 25 S., R. 18 E., M. D. M., as described in our VIIth Report, p. 67. Inflammable gas is found at the Barker ranch, in Sec. 5, T. 29 S., M. D. M., as recorded in this article. On the eastern side of the valley, however, the showing of hydrocarbons is insignificant compared with that on the western side. This may be partly accounted for by the fact that the geological disturbance of the Tertiary rocks on the western side is very great, while on the eastern side it is very slight. Moreover, it is not improbable that on the eastern side of the valley the formations contemporaneous with the rocks yielding oil on the western side are overlaid by more recent Tertiary strata, in which the hydrocarbons are not very abundant. On the eastern side of the valley, the Tertiary formation is well represented, as shown by fossils collected in the vicinity of the Rio Bravo ranch. The writer obtained a small collection of Tertiary fossils at the San Emidio ranch, from strata overlying the formations which yield oil in the Sunset District, and a few from the oil-yielding rocks themselves.

The numerous Pliocene fossils collected near the Rio Bravo ranch led to the conclusion that the formation exposed in that vicinity is more recent than at San Emidio, although it would not be safe to assert such a generalization without obtaining a greater number of specimens from both localities. It is probable that Tertiary strata underlie the more recent formations in the valley lands of Kern County, unless there has been a much greater erosion of the Tertiary rocks than there is any reason to suspect.

As can be seen by examining the record of the strata penetrated by wells which have been sunk for water in the valley lands of Kern and Tulare Counties (see our XIth Report, pages 233, 485), the recent filling of the valley appears to contain sufficient clayey strata to serve as a cover under which gas could be stored in underlying porous formations. A review of the situation, therefore, warrants the opinion that deep borings in the valley lands of Kern County would be quite likely to penetrate gas-yielding and possibly oil-yielding strata. The petroleum and gas-yielding formations of Kern County will now be considered more closely, beginning with the Sunset Oil District, on the western side of the valley.

TOPOGRAPHY OF THE SUNSET OIL DISTRICT.

The territory comprising what is locally known as the Sunset Oil District (although no such mining district has been organized) is situated in the first two tiers of the northeastern foothills of the Coast Range, which rise to the southward of Buena Vista Lake, and stretches out a short distance into the mesa lands which form the southern border of the San Joaquin Valley in Kern County. The two tiers of foothills mentioned commence in the most northeasterly portion of the Templore Mountains, and extend in a southeasterly direction until they sink in the rolling mesa lands. A bird's-eye view of this locality from a suitable eminence on the mountains to the southward demonstrates the fact that these foothills are but a remnant of what was once a much more extensive formation. In the western portion of the territory under discussion a large gap, coinciding with the bed of Bitter Water Creek has been eroded nearly at right angles to the prevailing strike of th country rock. Another valley, as shown on the sketch-map heret appended, has been worn in a direction nearly parallel to the prevailing strike of the formation; this valley almost cuts off the first tier of hills which are composed mainly of light-colored shale, from a second tier i which sandstone predominates.

At two other places, shown respectively on the sketch-map as "Cienega Creek and Bitter Creek, ravines have been cut through the hills transversely to the prevailing strike of the country rock; and they are occupied by the dry beds of the creeks named. Opinions differ with regar to the correct name of Cienega Creek, hence it is marked "Cienega?" on the accompanying sketch-map.

The rocky strata throughout the foothills forming this portion of the Coast Range are greatly obscured by soil, upon which fair grazing is furnished during the spring. The continuity of this heavy mantle of alluvium no doubt results from the scarcity of rain. During the winter, violent storms occasionally send torrents down the channels, which in some places cut so deeply into the earth as to expose the rock beneath. For the rest of the year, these dry creek-beds are the embodiment of aridity, except when there is a cloud-burst in the mountains. These cloud-bursts occur during thunder storms, usually during the summer time, and they give rise to muddy debacles, which sweep with resistless force through the parched watercourses, tearing off huge masses of the softer formations, and strewing the mesa lands with blocks of harder rock from the higher portions of the Coast Range. Some of these creek-beds are white with effervescent salts, and in places they are moistened by saline springs. There is no potable water in the Sunset Oil District.

To the southward of the district, tier after tier of mountainous ridges rise toward the dominant ridge of the Tehachapi range, as this portion of the Coast Range is named upon the Kern County map. The northeastern slope and the greater portion of the summit slope of the Tehachapi range is covered with alluvium. On the summits of these mountains there are not only grazing, but agricultural lands. Potable water is found in springs, and also by digging in the bottom of ravines; and although the writer is informed that several dry wells are often dug before water is obtained, the water supply appears to be sufficient for the requirements of the inhabitants.

THE GEOLOGY OF THE SUNSET OIL DISTRICT AND ADJACENT TERRITORY.

The rocky formations which impinge on the southern portion of th Sunset Oil District, constitute the mountainous ridges previously mentioned on the northeastern slope of the Tehachapi range. These ridge are, for the most part, formed by flexures in the stratified rocks, whic create, as it were, subsidiary anticlinals, some of which are very acut their slopes frequently presenting an angle of more than 60°. The strik of this formation, in a general way, is southeasterly and northwesterl These rocks yield springs of sulphuretted and saline water, and of potable water at a few places in the higher portions of the mountains. It said that at one place in this formation there is a seepage of oil. No fossils were found in this formation, but its lithological character resembl that of the San Emidio Cañon, where a small collection of fossils w obtained. Dr. J. G. Cooper found these to consist of two orders: (*a*) Fossils from thick sandstone strata, which are referred by him to the Tejon group of the Cretaceous system; (*b*) Miocene fossils, also from thick sandstone strata.

The rocky formations of the Sunset Oil District will now be enumerated in what appears to be the order of their relative stratographical superposition. The geological periods to which they respectively belong can only be inferred from the few poorly preserved fossils obtained in this locality, and from the physical resemblance of the rocks themselves to the rocks of other formations on the eastern slope of the Coast Range, which are richer in palæontological evidence. The most ancient series of rocks exposed in the Sunset Oil District consist of sandstone, calcareo-silicious rocks and impure limestone, dark-colored earthy and sandy shales, massive light-colored shales which show a hackly fracture, strata of sandstone with rounded concretions, calcareous sandstones, and fine calcareous conglomerate. The exposures of formation are scarce, and the few that exist show great geological disturbance. Within short distances the strata frequently dip in opposite directions and at different angles of inclination; the prevailing dip, however, appears to be northeasterly.

These rocks are best exposed along what appears to be the axis of a flexure, which forms the second tier of foothills which rise to the southward of the mesa-land. A general view of the situation leads to the conclusion that this flexure has been modified, not only by erosion, but by faulting. This formation yields springs of sulphuretted brines, and in one place (Station 52; see sketch-map) a small quantity of greenish oil accompanies the brine; but no tufa nor any solid bituminous deposit is formed. No fossils were found in this formation. The most striking characteristic features of this formation are the earthy and sandy shales, and the sandstone containing rounded concretions. It may here be remarked that similar shales and sandstones constitute Late Cretaceous strata, which are found beneath light-colored silicious shales in the oil district 9 miles north of Coalinga, in Fresno County.

The next formation is composed mainly of light-colored silicious shales, and constitutes the first tier of foothills. These shales are frequently of a brownish color when first mined, but they become almost white under the action of the atmosphere; indeed, the outcroppings of this rock are white or light-colored for several feet beneath the surface.

This light-colored silicious shale is by far the most characteristic rock of the bituminous formations; much of it is of low specific gravity, is porous, sticking readily to the tongue, and is easily scratched; some of this shale, however, especially in the lower portion of the formation, is indurated, apparently by the infiltration of silicious water. Occasionally pieces of this shale are found which show silicious induration only in the outer portions of the laminæ of which it is composed, and a cross fracture reveals soft, light-colored shale within. The chemical composition of these shales is as interesting as their physical appearance, the characteristic feature being the large amount of silica they contain. Two specimens from the Sunset Oil District were examined, which showed as follows:

	Insoluble in Acid.	Silica Soluble in Sodium Carbonate.	Total Amount of Silica.
(*a*)	99 per cent.	12 per cent.	98 per cent.
(*b*)	91 per cent.	24 per cent.	89 per cent.

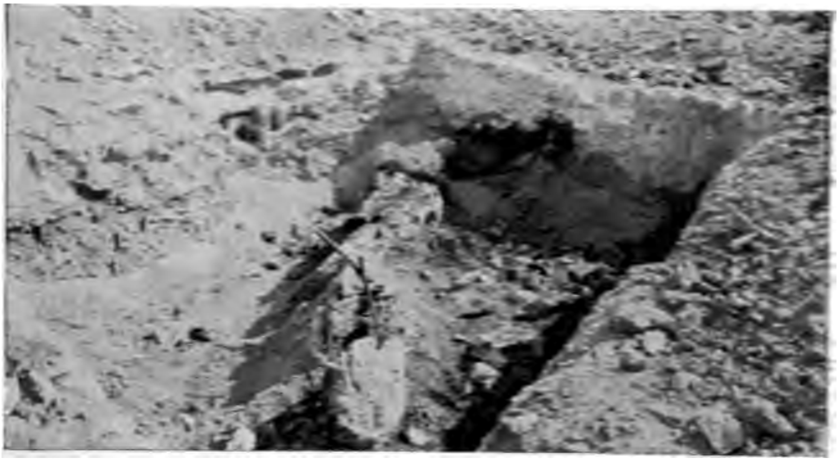
Only very small quantities of alumina were present in these specimens; indeed, one gramme of the shale did not yield a sufficient quantity of alumina for accurate estimation. The only other constituent of the portion of the shale which was insoluble in acid was a little iron. The constituents soluble in acid were not worked out; qualitatively (*a*) showed iron and a little lime; (*b*) showed iron, lime, and magnesia.

In some places these light-colored shales are interstratified with sandstone, and also with calcareo-silicious strata. The sandstone is seldom many feet in thickness, frequently only a few inches. The granules of which the sandstone is composed are usually individualized, although in some instances they appear to be metamorphosed and emerged in a silicious mass. There are also a few loosely coherent sandy strata, which are scarcely compact enough to be called sandstone; they are usually micaceous, and sometimes saturated with petroleum. The silicious rocks, as far as macroscopic inspection can determine, are amorphous, and they frequently possess a cleavage resembling the soft, silicious shales with which they are interstratified. Many of these silicious rocks are calcareous, varying from a flinty rock, which shows a slight reaction with hydrochloric acid, to a silicious limestone. These hard strata ("shells," as the well-borers call them) are usually either white or buff-colored, but occasionally they are reddish brown, at least such is their appearance where they crop out at the surface of the ground. These silicious strata, like the shales they interstratify, are darker colored at some distance beneath the surface. The reason of this change in color probably is that underground the rocky formation includes some moisture and bituminous matter, which evaporates when the rock is brought to the surface; also that the iron contained by rocks beneath the surface is in the ferrous condition, which changes to the ferric on exposure to the air.

The light-colored shales are much less disturbed than the formation on which they rest. The direction of the dip of the light-colored shales in the Sunset Oil District varies from 5° to 35° east of north; and the angle of inclination is in some places as low as 20°, while in others it is as high as 80°. The northerly direction of the dip appears the most pronounced in the eastern portion of the district, and the angle of inclination increases toward the bottom of the formation. On the Santa Jaga Creek, however, in the eastern extremity of the district, the dip is southwesterly, and at an angle of less than 20°. At several places in this light-colored shale there are seepages of heavy, black oil, with springs of sulphuretted brine and saline water; and the heavy oil has formed beds of solid bitumen, as hereinafter described.

In the eastern extremity of the Templore Mountains, where the first tier of foothills which traverse the Sunset Oil District appears to culminate, the formation is almost entirely light-colored shale. The dip of this shale in these mountains warrants the belief that that formation been thrown by flexure into two short anticlinals. It is no great

Asphaltum Bed at Salt Marsh, Sunset Oil District, Kern County.



Sulphur Deposits, Sunset Oil District, Kern County

Peculiar Erosion in Sandstone underlying Light-Colored Shale. Sunset Oil District, Kern County.

tretch of the imagination to suppose that if the strata forming such
nticlinals were prolonged to the eastward, the northern slope of the
outhernmost anticlinal would correspond to the main body of the light-
olored shales which yields the heavy oil and brine in the Sunset Oil
istrict; and that the northern slope of the northern anticlinal would
orrespond to the strata which furnish the springs of heavy oil and brine
t Salt Marsh, in the northern extremity of the district. These features
an be further observed in the accompanying sketch-map by noting the
irection of the arrows showing the dip of the light-colored shale; but
he erosion which has taken place, and the alluvium with which the
ills are covered, render the expression of opinion hazardous.

Although the southern limit of the light-colored shale in the district
tolerably well defined, it is not unlikely that in some places, where
is shale has escaped erosion, it may extend a long way up the north-
stern slope of the Coast Range. In one instance a well was dug at
altitude of nearly 3,000 feet, in which light-colored shales similar in
ppearance to those found in the lower foothills were penetrated.

At two oil seepages in the northern edge of the light-colored shale for-
ation, viz.: a short distance southwest of Flag No. 3, and at Station
o. 66, as shown in the sketch-map, there are calcareous strata contain-
g marine shells. Only three specimens, however, were obtained which
ere sufficiently perfect for identification. These were found by Dr.
ooper to be of the latest Tertiary epoch:

pes staleyi, Gabb	Pliocene.
acoma inquinata, Desh.	Living, Pliocene.
ya arenaria, Linn.	Living, Pliocene.

The fossiliferous strata are situated near the southern edge of
ndstones which dip in a northerly direction. The remnant of this
ndstone formation which is exposed in the district is insufficient to
arrant much being said upon the subject.

Last in order come the formations which are but little disturbed, some
which are practically horizontal. With one exception the opportu-
ties for examining these deposits in the Sunset Oil District are still
ore rare than in the case of the underlying Tertiary sandstones.

Briefly these horizontal formations are as follows:

(*a*) Hard, white, silicious sandstone, which appears to have been
durated by infiltering water. This rock is exposed about two miles
rthwest of the oil springs at Salt Marsh, where it shows a thickness
about 60 feet; also at the sulphur deposits near the Sunset Oil
ell.

(*b*) A soft, white, gypseous rock, which rests uncomformably on the
ler formations. In the eastern portion of the Sunset Oil District, and
out a mile eastward therefrom, this white, gypseous rock attains a
ickness of several feet, and forms low hills upon the mesa-land. It
n also be seen resting upon the upturned edges of older strata at an
titude of nearly 2,000 feet. A specimen of this white rock was exam-
ed in the laboratory of the California State Mining Bureau and was
und to be composed of sulphate and a carbonate of lime and clayey
atter.

(*c*) Soft, friable sandstones, which can be seen in the low hills adja-
nt to the oil springs at Salt Marsh.

(*d*) Travertine, calcareous tufa, and breccia, containing numerous fragments of light-colored shale. These rocks can be seen near the brine and oil springs, a short distance to the northwest of Flag No. 5.

MINERALS, OIL CLAIMS, AND BITUMINOUS DEPOSITS OF THE SUNSET OIL DISTRICT.

The mineral products of the rocky formations of the Sunset Oil Di trict are inflammable gas, petroleum, asphaltum, mineral water, sulphu and gypsum. Of these minerals, those to which this article is princ pally devoted are the hydrocarbon compounds. These occur as g and oil, which are yielded by natural springs and by wells which ha been bored, and also as superficial deposits of oil-soaked earth or rock, an as beds of asphaltum; the latter, no doubt, are caused by exudations c heavy oil from which the lighter naphthas have evaporated, and whic have undergone a partial oxidization.

The group of oil and sulphur claims which constitute what is locall known as the Sunset Oil District are as follows: The Jewett and Blodget claims, the Bakersfield, the Texas, the Oil Queen, the Ravena, and th Sulphur claims. As shown in the accompanying sketch-map, thes claims extend diagonally about 6½ miles in a northwesterly and south easterly direction, viz.: from Sec. 2, R. 24 W., T. 12 N., S. B. M., to Sec 27, R. 23 W., T. 11 N., S. B. M.

In this district by far the greatest amount of development has bee done by Messrs. Jewett and Blodgett, of Bakersfield, on the Sunset, th Jewett and Blodgett, and the Bakersfield claims.

The first mineral of the Sunset District placed upon the market b Messrs. Jewett and Blodgett was asphaltum, obtained principally i Section 20 from a bed of asphaltum through which most of the well marked on the sketch-map as *Oil Wells, Group 1,* are sunk and from sta tions marked No. 9 and No. 10, respectively. When the mining of asphal tum was first commenced at *Oil Wells, Group 1,* there was a bed o asphaltum, which extended over several acres, varying in thickness fro 3 to 25 feet or more. This asphaltum, which was of different degrees o purity, existed not only in exposed mounds, but was found by excavatio to extend in some places beneath the superficial drift. In the asphaltu the bones of animals were discovered, as well as some stone mortars, th latter being found beneath 4 or 5 feet of asphaltum. The beds of asphaltum at Stations 9 and 10 present similar characteristics to the asphaltum at the oil wells, and trenches which have been cut through the asphaltum show it to be very similar, both as to quality and depth. The superficial asphaltum is of good quality, but beneath it the asphaltum is dr and pulverulent and mixed with earth. The dry asphaltum is used fo fuel. In several places heavy oil oozes through the asphaltum. Th asphaltum is principally black, pitch-like bitumen, varying from solid t viscous; some of it, however, is yellowish in color.

An asphaltum refinery was erected at the Sunset Oil Wells by Messrs Jewett and Blodgett, the process employed for refining the asphaltu being similar to that hereinafter described as used at Asphalto. The ra material yielded from 50 to 75 per cent of refined asphaltum. Abou 1,200 tons of refined asphaltum were shipped from these works durin 1892. The best quality of raw material in these beds has been worke up, and the refining of crude asphaltum was discontinued at the Sunse Oil Wells when the Southern Pacific Railroad Company extended it branch line to Asphalto, about 30 miles distant, where there are deposits of asphaltum near the railroad. The cost of producing refined asphaltum at the Sunset works was about $10 a ton, not including wear and tear of plant. The cost of transportation by wagon from the Sunset Oil Wells to Bakersfield was $6 a ton.

OIL WELLS OF JEWETT AND BLODGETT.

Messrs. Jewett and Blodgett bored two groups of wells in the mesa lands of the Sunset Oil District. One of these groups, which is marked "*Oil Wells, Group 1,*" on the sketch-map, is in Section 21; and the other, marked "*Group 2,*" is in Section 28. In Group 1 there are thirteen wells, one of these being 1,300 feet in depth, the remainder varying from 80 to 500 feet in depth. The 1,300-foot well yielded flowing water and much gas; the others yield a heavy oil by pumping. The twelve oil-producing wells are all situated within an area of about 400 feet in length and 30 feet in width. The 1,300-foot well was bored a short distance in a northeasterly direction from the most northerly of the oil-yielding wells. The twelve oil wells yield altogether about 15 barrels of oil every twenty-four hours. The specific gravity of this oil varies in the different wells from about 12° Baumé to a heavy liquid asphaltum that requires to be heated by steam, which is forced to the bottom of the well, before the heavy oil can be pumped. Six of these are dry wells, and are sunk to a depth of from 80 to 100 feet. The stratum yielding the greater portion of the heavy oil is about 35 feet in thickness. The other six are drilled wells varying from 150 to 500 feet in depth. All these wells are sunk to a sufficient depth to form reservoirs at the bottom capable of storing the oil which gathers during several days, for a few hours of pumping is sufficient to pump the oil accumulated during twenty-four hours. Each well is furnished with a pumping-jack, consisting of knee and frame, which is securely anchored to the ground or mud sills. All these wells are pumped with lift pumps, which have a 4-inch working barrel, pumping from the bottom. It is necessary to pump heavy oil at a very low rate of speed; indeed, the speed employed is only four strokes of two feet a minute. All the pumps are worked simultaneously by connecting rods which are attached to a large oscillating wheel, run by a 10-foot driving-wheel. (See illustration in our XIth Report, p. 233.) The power is supplied by a fifteen horse-power link-motion, single-action engine. This pumping plant, together with the engine and boiler, is run by one man.

This method of simultaneously pumping so many wells from one source of power, and at different angles, was devised by Mr. E. Youle, the Superintendent of the Sunset Oil Works, and of the works of the Standard Asphalt Company, at Asphalto. The oil is pumped by this method from the wells into two tanks, each of which is 12x20x2 feet in dimensions. In these tanks, the heavy oil, which is accompanied by more or less water, is heated by steam coils to a temperature of from 212° to 220° Fahr. This lessens the specific gravity of the oil, and allows it to rise to the surface of the water. As much water as possible is drawn from the bottom of the tanks, and the remainder, which is entangled in the oil, is expelled as steam, by increasing the temperature in the tanks. The oil is then conducted by a 3-inch pipe from the tanks to two refining kettles, each of which is 12 feet long, 5 feet wide, and 3 feet deep. These kettles are set in brick work, and in construction resemble those hereinafter described at Asphalto, the only difference being that the former are furnished with air-tight lids, fitted with goose-neck pipes connected by unions with a coil and condenser.

The process of refining the oil is as follows: As soon as a kettle is filled, the lid is left partially open, until the oil will stand a temperature of 300° Fahr. without foaming. During the early stage of this process the man in charge has constantly to watch the contents of the kettle, and so to regulate the heat as to prevent the oil from foaming. When the oil remains perfectly still, at a temperature of 300° Fahr., the cover is screwed down, and the temperature of the oil is gradually heated to 550° Fahr. The vapors given off are drawn into the condenser pipe by a suction produced by an air-compressor blast, and the expansion of the air, as it leaves the compressor, maintains the water in the condenser-box at a low temperature. During the entire process the oil is constantly stirred by a stirrer, consisting of paddles attached to a shaft which runs through the kettle. This stirrer is worked by a wire cable running from the oscillating wheel in the power-house, which also works the pumps, as previously described.

The crude oil yields about 50 per cent of distillates, which have an average specific gravity of 20° B. The heat is increased toward the end of the process to 700° Fahr., in order to expel the heavier distillates and make the refined asphaltum hard. It is the intention of the Sunset Company to treat these heavy distillates by fractional distillation; and at the time of the writer's visit these distillates were being stored in tanks for that purpose.

During the process of refining, the oil is from time to time drawn from stop-cocks in the kettles and tested. The process is considered completed when, on withdrawing a sample of the residue and pouring it into water, it forms a hard, black, lustrous substance, which bends slightly, and breaks under a moderate pressure of the hand. The residue, which consists of refined asphaltum, is then discharged into a kettle suspended on a carrier. This kettle is furnished with a swing-pipe, through which the refined asphaltum is drawn off into boxes in a manner hereinafter described when speaking of the process of refining asphaltum at Asphalto.

The fire-boxes under the kettles at the Sunset works, like those at Asphalto, are furnished with grate bars formed of iron pipe. The fuel is the dry crude asphaltum. The manager of the Sunset works states that the asphaltum made in these oil kettles is 100 fine, and that it is used in the manufacture of printing ink and varnish.

RECORD OF OIL WELLS, GROUP 1.

The following records show the character of the formation penetrated by the wells belonging to Group 1:

Well No. 1.

Bored in March, 1891. This well was commenced with 11-inch casing.

Surface drift, to a depth of	50 feet.
Light-colored shale, to a depth of	400 feet.
At this depth mineral water rose to within 40 feet of the top of the casing.	
Black sandy shale, to a depth of	559 feet.
At this depth the diameter of casing was reduced to 8⅝ inches.	
Black sandy shale, with black sulphur water, to a depth of	610 feet.
At this depth, casing reduced to 6⅝ inches.	

Black sandy shale, to a depth of	700 feet.
Gas from this depth burned with a flame 4 feet high from a 7-inch pipe.	
Black sandy shale, with oil in seams, to a depth of	900 feet.
At this depth, casing reduced to 5⅝ inches.	
Very light-colored shale, to a depth of	928 feet.
Gray sand rock, with flowing water, to a depth of	995 feet.
At this depth the well flowed 50 barrels of mineral water daily, and yielded much gas but little oil.	
Light-colored shale, to a depth of	1,235 feet.
Dark-colored shale, which caved badly, to a depth of	1,250 feet.
At this depth, casing reduced to 4⅞ inches.	
Dark-colored shale, to a depth of	1,290 feet.

The first gas was noticed at a depth of 600 feet, and two other distinct flows were struck at depths of 928 and 1,200 feet, respectively.

Well No. 2.

Asphaltum, to a depth of	30 feet.
Dark-colored shale, with a small amount of oil, to a depth of	60 feet.
Dark-colored shale, with more oil, to a depth of	130 feet.
Light blue shale, with either oil or water, to a depth of	500 feet.

In this shale a thin stratum of light blue sand was passed through.

Well No. 3.

Asphaltum, to a depth of	40 feet.
Dark-colored shale, with some oil, to a depth of	110 feet.
Light blue sand, to a depth of	160 feet.

Well No. 4.

Asphaltum, to a depth of	50 feet.
Drift from the mountain, to a depth of	65 feet.
Shale, with some oil, to a depth of	70 feet.
Dark-colored shale and oil, to a depth of	130 feet.
Dark-colored shale, without oil, to a depth of	160 feet.
Light-colored shale, to a depth of	237 feet.

About 40 or 50 barrels of mineral water flowed from this well daily.

Well No. 5.

Asphaltum, to a depth of	25 feet.
Dark-colored shale, to a depth of	50 feet.
Dark-colored shale, with oil, to a depth of	121 feet.
Dark-colored shale, without oil, to a depth of	150 feet.
Light-colored shale, without oil, to a depth of	185 feet.

There was no water in this well.

Well No. 6.

Wash and drift, to a depth of	30 feet.
Dark shale and oil, to a depth of	75 feet.
Dark shale, without oil, to a depth of	120 feet.

The boring ended in light shale. There was no water in this well.

Well No. 7.

Light-colored shale, to a depth of	82 feet.
Dark-colored shale, with oil, to a depth of	175 feet.
Light-colored shale, to a depth of	215 feet.

There was no water in this well.

Well No. 8.

Yellow hardpan, to a depth of	15 feet.
Dark-brown wash and gravel, to a depth of	47 feet.
Dark-colored shale, with a slight showing of oil, to a depth of	110 feet.

Beneath the dark-colored shale a greenish shale was penetrated for a few feet. This greenish shale yielded brackish water, which filled the hole to within 15 feet of the top. After the well had been shut down for some days heavy asphaltum oil accumulated in the casing to the depth of about 60 feet. Mr. Youle, the Superintendent, is of the opinion that the stratum yielding the oil lies at the depth of about 110 feet.

Well No. 9.

White soil	20 feet.
Greenish soil and gravel	35 feet.
Hard "shell"	2 feet.
Dark-colored "mushy mud"	63 feet.
Brown shale, intercalated with sandy "shells" and streaks of green sand; "cavy" formation	42 feet.

Water was struck at the depth of 180 feet.

Well No. 10.

Earth and drift	40 feet.
Blue clay	30 feet.
Brown shale	130 feet.

There was no oil below the depth of 70 feet.

As will be seen from the accompanying sectional map, these wells are situated along a strip about 400 feet in length, which has a course of about 57° west of north. A large pile of material has been taken out of these wells, and the fragments of shale, of which it was principally composed, have become light-colored under the action of the atmosphere. No fossils were found amongst this material, but its physical appearance left no doubt but that it belongs to the light-colored shale formation previously described as constituting the first tier of foothills in the Sunset Oil District.

RECORD OF OIL WELLS, GROUP 2.

In 1892–93 Messrs. Jewett and Blodgett bored three wells on the mesa lands in Section 28, at a point a little more than a mile distant from Oil Wells, Group 1, and in a southeasterly direction therefrom. These last bored wells are marked on the sketch-map as Oil Wells, Group 2. The following records show the character of the formation penetrated:

Well No. 1.

This well was commenced with a 11½-inch casing.

Sulphur and apparently tufa deposited by mineral water	45 feet.
Very hard gray and blue sandstone	80 feet.
At a depth of 58 feet there was a little oil and some mineral water.	
Gray sandstone, with soft streaks and more mineral water	160 feet.
At this depth the casing was reduced to 8⅝ inches.	
Soft blue sandstone, with hard "shells" and more water	402 feet.
At this depth the casing was reduced to 6⅝ inches.	
Blue sandstone	420 feet.
At this depth the water was shut off.	
Coarse sandstone, with oil and water and much gas	440 feet.
Light-blue sand	445 feet.
Sand, with water	820 feet.

This well was cased from the depth of 420 feet to that of 820 feet with 5-inch casing. Superintendent Youle states that this well was tested, and that about 100 barrels of brine and 6 barrels of oil were pumped from it daily for three months. It also furnished enough gas for a cook-stove.

Well No. 2.

This well is situated about 200 paces a little south of west from Well No. 1.

Earth and gravel	60 feet.
Blue sandstone with some very hard streaks	175 feet.
Gray and bluish sandstone	430 feet.
This stratum yielded daily about one barrel of oil mixed with water.	
Sandstone, first soft then hard (more oil and water)	535 feet.
Soft sandstone, passing into hard sandstone with streaks of mud (more water, oil, and gas)	660 feet.
Sand, with a little oil and much water	820 feet.

This well was cased with 8⅝-inch casing for the first 245 feet, and below that depth with 6⅝-inch casing. The writer is informed that about 150 barrels of sulphuretted mineral water and 4 barrels of oil were pumped from this well in twenty-four hours.

Well No. 3.

This well is situated about 150 paces a little east of south from Well No. 2.

For the first 300 feet a similar formation was penetrated to that passed through in Wells No. 1 and 2	300 feet.
Bluish gray sandstone, with an occasional streak of darker colored and sharper sand	755 feet.
At this depth there was much gas and a little oil. At the depth of 540 feet the water was shut off with 6⅝-inch casing.	
Brown sand, with considerable oil	815 feet.

Barren sandstone	940 feet.
Oil-bearing sandstone	950 feet.
Light-blue sand	1,030 feet.
At this depth a blue clay impeded drilling.	
Dark-blue sandstone, with more gas	1,060 feet.
Light-blue sandstone, with more gas	1,180 feet.
At this depth there was an increase in the amount of gas and oil.	
Sandstone	1,210 feet.
Black shale	1,215 feet.
Sandstone	1,220 feet.
Close-grained shale, with more oil	1,270 feet.
Oil sand	1,295 feet.
Coarse sand	1,350 feet.

It is the gas from this well which was used in the experiments on the fuel value of the gas at Sunset, as hereinafter recorded.

The oil yielded by the oil wells of Group 2 is a dark green oil, and possesses a lower specific gravity than that yielded by the oil wells of Group 1.

OTHER OIL SEEPAGES AND OIL WELLS.

At Station 64, in what is known as Robber's Gulch, there is a seepage of heavy oil, and a small amount of asphaltum has been formed. (See sketch-map.) The upper portion of the oil-yielding formation at this point is a fossiliferous sandy limestone, in which the fossils are very poorly preserved. Beneath the fossiliferous stratum is a soft, gray sandstone, about 100 feet in thickness; and beneath the soft, gray sandstone is an oil-soaked stratum of sandstone, which rests upon light-colored shale, interstratified with thin courses of sandstone. The outcropping shale shows a thickness of about 100 feet; this formation dips 13° west of north at an angle of about 55°. The shale exhibits considerable flexure.

In the cañon to the west of Flag No. 3, there is another bed of asphaltum, which extends up the cañon for about 200 yards. In these asphaltum beds there are several springs of heavy oil, which flow feebly during hot weather. At the base of the hill on which Flag No. 3 is situated, fossiliferous strata are exposed. The strata containing the fossils, and the soft, sandy strata composing the hill to the northeast of the fossiliferous formation, appear to dip in a more easterly direction and at a less angle than is the case with the light-colored shales on which they rest.

A short distance farther southward, at Station 6, light-colored shale crops out, which is intercalated with bituminous sandstone. This formation pitches about 30° east of north, and at an angle of about 54°.

In the mouth of the cañon about half a mile westward from Flag No. 3, there is another irregular deposit of asphaltum; and at point C a well was bored, it is said, to the depth of 1,300 feet. This well flows about 500 barrels of salt water daily. A little oil and some gas accompany the salt water, which flows with spasmodic energy. A small amount of oil also oozes up around the outside of the casing.

A hundred yards or so in a southeasterly direction from the flowing well, another well was bored to the depth of 70 feet. This well must be nearly full of oil, for a heavy black oil could be easily pumped with what was said to be an ordinary suction-pump, which was fixed in the casing.

Near the mouth of the cañon to the westward of the flowing well, there is another small bed of asphaltum. At the entrance to this cañon there is a series of ledges of travertine, which are practically horizontal. In some places this travertine contains fragments of light-colored shale; some of the travertine is vesicular, and the vesicles are filled with petroleum. Here and there asphaltum has flowed over the travertine, but its source is obscured by drift from the mountain. The formation to the southward is principally light-colored shale, which at Flag No. 5 is interstratified with whitish sandstone, and at one point contained sections of what appear to be fish vertebræ. At this point a thin stratum of gypseous material rests unconformably on the upturned edges of the shale and sandstone strata, which dip 45° east of north at an angle of about 40°. To the southward of Flag No. 5, light-colored shales and silicious shales predominate. The abraided edges of these shaly strata are worn off level with the surface of the ground and form broad bands, which traverse the barren country, with a strike of about 60° east of south. In some places slight flexures in these strata are very distinctly marked on the slopes of the bare hills.

Extending in a northwesterly direction from Flag No. 5 are a series of springs, which yield sulphuretted and saline water, and a small amount of heavy oil. Two of the principal springs, which yield sulphuretted water are situated at Stations 21 and 22, and between them are several other seepages of mineral water. (See water analyses at end of bulletin.) These springs have deposited a large amount of tufaceous matter, some of which is calcareous. The springs give off a large amount of sulphuretted hydrogen. In their vicinity there is a saline crust on the surface of the ground. Beneath this crust the soil is pulverulent, and sustains a growth of bright-green plants, which flourish in the saline soil, and they show a marked contrast to the faded whity-green of the sagebrush. Specimens of these plants were examined in the herbarium of the California Academy of Sciences, and found to be *Spirostachys occidentalis*, *Nitrophila occidentalis*, and *Distichlis maritima* (salt grass).

In the hills which rise to the northwest of these springs the formation is much obscured by alluvium. In some places light-colored shales crop out, but the strata are flattened or undulating, and in two places near Flag No. 7 they dip to the southward, as shown on the sketch-map. The physical appearance of the shale forming these flattened strata is somewhat different from that of the light-colored shale yielding heavy oil.

At Salt Marsh there are several springs of sulphuretted brine, some of which deposit tufa. The course of the salt formation to the westward is marked by bright-green plants similar to those previously mentioned. At Salt Marsh there is an asphaltum bed of about five acres in extent (see illustration), but it appears to be a comparatively thin layer. This asphaltum bed is nearly surrounded by low hills. Most of these hills are covered with alluvium, but in the principal hill there are a few outcropping ledges of light-colored shale and sandstone, which show an average dip of about 30° east of north, at an angle of about 60°. From one of the sandstone strata a few specimens of very small pectens were obtained, but they were too imperfect for identification. These peculiar features of soil and vegetable growth are also characteristic of other localities in the oil-bearing formations of the Coast Range, where the ground is moistened by the waters of saline springs.

A few hundred yards to the eastward of Flag No. 8 what appears to be a more recent formation than the light-colored shales has been cut through to make a roadway. This formation consists of friable sandstone and sandy shales, containing fragments of light-colored silicious shale. The dip is to the east of north at an angle of not more than 30°. A short distance to the northeast of Flag No. 8, a well was bored to the depth of 325 feet. This well yields a small stream of sulphuretted brine, which is accompanied by inflammable gas and a small amount of oil.

OIL CLAIMS EAST OF SECTION 28, T. 11 N., R. 23 W., S. B. M.

In the mesa lands and low foothills which lie to the eastward of the Oil Wells, Group 2, there are several oil and sulphur claims. The writer, however, made only a brief reconnoisance of this portion of the Sunset Oil District, and for the following reasons: (1) Because it was obvious that the geological formation is so obscured by alluvium and drift that much work might be done and a great deal of time spent in vainly searching for outcropping rocks. (2) Because very little development had been made on these claims. (3) Because the geological formation was evidently similar to that of the portion of the Sunset Oil District herein described, where extensive developments have been made, and where there are rock exposures by which the oil-yielding strata may be examined.

The principal developments that have been made in this portion of the Sunset Oil District are two wells on the Texas claim, owned by Hambleton and others. One of these wells is 18 feet in depth, the material passed through being earthy decomposed sandstone. The man who dug the well says that the strata of sandstone which he penetrated are standing nearly vertical, and that oil and gas were blown through crevices in the bottom of the well. The other well is situated about 100 yards south of the first, and at a slightly higher elevation. The formation passed through is sandstone. This well yields less oil, but more water and gas than the first one. At the time of the writer's visit these wells were partly filled with salt water, and with oil which floated on the surface of the water.

THE SULPHUR DEPOSITS OF THE SUNSET OIL DISTRICT.

Sulphur appears to be a concomitant of the oil-bearing formations, or rather of the more recent formations overlying them. The deposits of sulphur in Sunset Oil District and vicinity are found under the following conditions: (*a*) As drift cemented with sulphur; (*b*) as irregular masses of sulphur in the drift; (*c*) as sulphur encrusting or filling fissures in the rocks which underlie the drift and appear to rest unconformably on the oil-yielding formations; (*d*) as sulphurous earth; (*e*) as sulphurous precipitate in the waters of mineral springs.

Deposits of sulphur and sulphurous rocks and earth were observed at the following places in Sunset District:

At Station 27, as previously mentioned, there is a series of light-colored sandstones, some of which are very silicious and brecciated; they are practically horizontal, and taken together show a thickness of about 75 feet. Some of the lower strata of sandstone are impregnated with sulphuric acid or acid sulphur salts.

At Station 27*x*, which is situated about 150 yards west of Station 27, and at a slightly greater elevation, there is an outcrop of white, brecciated, clayey sandstone. Beneath the sandstone is a black, earthy, decomposed rock, containing sulphur; this rock is impregnated with acid, and has a fetid odor, which appears to result from the action of sulphuric acid on bituminous matter.

In the vicinity of the springs at Stations 21 and 22 there are acid, sulphurous earths, some of the latter being black and having a fetid odor. The waters of some of these springs are turbid with precipitated sulphur.

At Station 14 there are outcroppings of a light-colored sandstone, which is very acid to the taste.

At Station 58 the surface soil is pulverulent, and is apparently formed from a decomposed tufaceous material, while here and there some undecomposed fragments of the silicious rock protrude. Associated with the harder rocks is a soft, dark-colored, sulphurous formation, possessing a fetid odor. These sulphurous deposits extend for some distance, and have a trend of 80° east of north.

At Station 59 much sulphur is associated with partially decomposed sandstone, which has a strongly astringent taste. This rock is interstratified with a darker colored rock of similar structure. The whole deposit has the appearance of having undergone metamorphism from mineral springs or solfataric action.

The surface of the low hills on which Station 59 is situated shows sulphurous earth and sulphurous rock throughout an area of several acres. These sulphur deposits have been prospected by excavation to a depth of 10 or 12 feet, and have been found to consist of drift cemented with sulphur and acid decomposed rocks containing sulphur.

The sulphur-bearing formation evidently extends from Station 59 to Station 60. At the latter place an excavation shows a sulphurous deposit very similar to that at Station 59. At Station 60 there is an excavation which exposes a fissure varying from 2 to 6 inches or more in width, and having a direction of 65° west of north and east of south. The sides of this fissure are lined with high-grade sulphur ore, which extends for a distance of a foot or more on both sides of the fissure. The sulphur ore appears to be fine drift cemented with much sulphur.

On the eastern slopes of the low hills on which the principal sulphur deposits are situated, are several excavations, about 4 feet in depth, which show rich sulphur ore. These workings, which have been made in light-colored sulphurous rock and earth, also expose fissures from which "chimneys" of sulphur extend nearly to the surface of the ground. A man who dug some of these holes states that when the fissures were first opened they gave forth a strong flow of acid pungent gas. In these excavations the air is redolent with acid sulphurous gases, and the peculiar fetid odor before mentioned is perceptible in most places. (In the illustration of "sulphur deposit," the hammer and drill are placed upon a chimney of sulphur. The walls of the excavation shown are formed of sulphurous earth.)

A few hundred yards eastward from Station 60 there is an excavation about 10 feet in depth. This has been made all the way in high-grade sulphur ore, interstratified with dark-colored and acid sulphurous earth. Lateral extensions of this excavation have been made to the depth of 4 or 5 feet; in some of them solid sulphur has been struck, and in all the earth is acid and sulphurous. The massive sulphur exposed in this pit is of a grayish color, and some lying on the dump was coated with lemon-colored crystals of sulphur. From this excavation a decomposed sulphurous formation extends in a northeasterly direction, and prospect workings encountered an acid-tasting sandstone at a depth of about 5 feet. In many places what appears to be a tufaceous deposit is exposed, which, on weathering, forms a white silicious rock. Still farther eastward there is a recent formation containing numerous small fragments of light-colored shale. In some places these fragments form a breccia. This superficial formation pitches to the southward.

Deposits of sulphur and sulphurous earth, similar in character to those already mentioned but of less extent, are exposed at intervals in an easterly direction across the mesa lands between Stations 60 and 67. Thus a line of sulphurous deposits extends in an easterly direction for more than a mile between Stations 59 and 67. There are, as already mentioned, numerous springs in the Sunset Oil District which yield sulphuretted water.

Since so many have evinced an interest in the history of these deposits, a few remarks on their probable genesis may not be out of place. If we turn to our chemical text-books, we find that when a solution of sulphuretted hydrogen is exposed to the air it soon becomes turbid, owing to the oxidization of the hydrogen and the consequent precipitation of the sulphur, the reaction that takes place being $(2H_2S+aq)+O_2=(2H_2O+aq)+S_2$. Also, that if the chemical action is assisted by the sulphurous vapors or solutions being absorbed by porous solids, the oxidization is more complete, and that the chemical reaction that then takes place can be expressed by the equation: $(H_2S+aq)+2O_2=H_2SO_4+aq$.

This view as to the formation of these sulphur deposits is strengthened by finding that many of the rocks in contact with the sulphur are acid with free sulphuric acid or acid sulphur salts, and that gypsum and alum usually accompany the sulphur.

With regard to the primordial source of the sulphuretted hydrogen, the probability is that it originated in the decomposition of the tissues of organisms, the carbonaceous constituents of which composed the petroleum and the hydrocarbon gases found in the Sunset Oil District. It is probable that such was the origin of the sulphur deposit referred to, and that the fissures through which the sulphur gases rise in the territory under discussion, allow the escape of such gases from the stratified rocks in which they were formed by chemical processes; not, as popularly supposed, that the fissures conduct the sulphurous gases from a volcanic source.

There are other deposits of sulphur and sulphurous earth in the southeastern borders of the Sunset Oil District, but they present similar characteristics to those already described.

GYPSUM.

The principal deposit of gypsum in the Sunset Oil District is situated in its southeastern borders. The gypsum forms a stratum of rather soft, chalky-looking rock, which in some places attains a thickness of several feet. Much impure gypsum is also found at and near the sulphur deposits previously described. A ravine, which is situated immediately to the east and southeast of Oil Wells, Group 2, cuts through a bank of this material to the depth of about 30 feet. This bank is composed of sedimentary strata, which appear to have been metamorphosed by the waters of mineral springs. The exposed rocks have the appearance of a friable white sandstone, containing much gypsum and kaolinized matter. In some places there are streaks and pockets of nearly pure kaolin and small masses of pure gypsum.

MINERAL WATER.

[See analyses of water at the end of this bulletin.]

REMARKS ON THE SUNSET OIL DISTRICT.

A review of the foregoing description of this territory, when taken in conjunction with investigations made in the oil district 9 miles north of Coalinga, in Fresno County, leads to the conclusion that there are two oil-yielding formations in the Sunset Oil District; but the paucity of palæontological evidence in this territory demands that such a conclusion be accepted tentatively. The most recent of formations, geologically speaking, consists principally of light-colored silicious shales, which practically compose the first tier of foothills. A line drawn across the sketch-map, in such a manner as to pass through the principal oil springs and asphaltum beds, shows that these oil seepages and asphaltum deposits are distributed along a line which corresponds very nearly with the prevailing trend of the light-colored shales, *i. e.*, about 70° east of south. It is also to be noticed that the different places where such oil springs and asphaltum beds are found in this formation have nearly the same altitude. These facts suggest that the principal oil-bearing strata are situated near the northern limit of the light-colored shales which are exposed at the Sunset Oil District, although it by no means necessarily follows that the rest of that formation is barren. The slight deviation of such oil seepages from a line coinciding with the prevailing strike of the formation is fully accounted for by local disturbances of the strata at many places in the territory under discussion.

The occurrence of these oil springs may be referred to two causes: (1) The cutting through of oil-yielding strata by erosion. In this connection the fact is recalled that many of the oil springs and beds of asphaltum are situated where cañons cut through the formation nearly at right angles to its strike. (2) In some instances the immediate cause of the oil springs may be referred to fracture of oil-bearing strata, by which means fissures are formed, which extend to the surface of the earth. As heretofore described, such fissures can be seen at the sulphur deposits in the mesa lands of the district.

The wells marked Oil Wells, Group 1, show what might be expected from wells penetrating the oil-yielding formations in the light-colored shales; and we should naturally expect that wells piercing the oil-yielding strata where there are no seepages of oil would yield better results than wells situated in localities where seepage has for ages been exhausting the contiguous oil-bearing rocks. That which is here assumed to be the second oil-yielding formation, immediately underlies the light-colored [illegible] marked on the sketch-map as Oil Wells, Group 2, appear to have been bored to prospect this formation. As previously mentioned, this lower formation is characterized by two things; namely, the absence of the peculiar light-colored shales such as compose the formation lying next in the order of upward vertical range, and the presence of dark-colored, argillaceous, earthy or sandy shales, which resemble certain shales found beneath the light-colored shales in the oil district nine miles north of Coalinga. These argillaceous, earthy shales can be seen near Station 52, where sulphuretted brine, accompanied by a little dark-green oil, issues from a soft sandstone. At Stations 49 and 49*a* there are also springs of sulphuretted and saline water, and earthy and sandy shales are exposed. Dark-colored shales can also be seen in the bed of the Cienega Creek, between Stations 32 and 33. If we journey in a southeasterly direction from the points named (which, notwithstanding much contortion of strata, appears to be the prevailing strike of this lower formation), we shall come out on the mesa lands in the vicinity of "Oil Wells, Group 2." Unfortunately, the heavy mantle of alluvium with which the hills are covered, and the disturbed character of this lower formation, prevent one from being able to speak with any degree of confidence concerning the stratigraphical position of the rocks penetrated by these wells. The writer searched diligently for geological evidence which would throw light on this subject, but the results are meager. Neither do the records of the strata penetrated during the process of boring "Oil Wells, Group 2," nor the character of the oil yielded by these wells when they were completed, solve this problem.

As will be seen by reference to the table of oil analyses at the end of this bulletin, the oils yielded by Wells Nos. 1, 2, and 3, both in their specific gravity and the character of their distillation products, resemble the samples of oil obtained from Tertiary strata, rather than the sample obtained from the Cretaceous formation at Coalinga. Moreover, whatever evidence might be deduced by a comparison of the oil yielded by "Oil Wells, Group 2," with oil obtained from strata of known geological age, is vitiated by the existence of such fissures as those found in the sulphur deposits of the Sunset Oil District. These rifts may penetrate formations of more than one geologic age, and occasion a blending of such oils as the strata contain. Moreover, deep-seated fissures are quite likely to induce an unusual oxidization of the hydrocarbons contained in the fractured rocks.

It is possible that a careful geological examination commenced at Mud Creek, and extended in a northwesterly direction, might tell something about the geologic age of the bench of sandstone in which "Oil Wells, Group 2," are bored. The brief reconnoisance in the vicinity of Mud Creek suggests that the Tertiary sandstones overlying the light-colored shales extend farther to the westward in that locality than they were observed to do in the Sunset District. Moreover, the heavy deposit of impure gypsum seen to the south of the Sunset Oil District resembles similar deposits on the eastern side of the San Joaquin Valley, which were probably formed during the Pliocene age.

The greatest drawback to a successful prosecution of the oil business in the Sunset District appears to be the large amount of water which accompanies the oil. In this connection, the fact must be borne in mind that the Sunset Oil Wells are bored at an altitude of something less than 1,000 feet, and that the maximum altitude of the anticlinal prospected by them does not exceed 2,000 feet. It is probable that there are portions of the Coast Range adjoining the Sunset District, where the oil-bearing formations extend to a much higher altitude than the anticlinal which has hitherto been prospected by boring; and that there may be extensive oil-bearing territory on the northeastern slope of the Coast Range, where no difficulty would be experienced from water. A partial analysis of the water obtained from Wells Nos. 2 and 3, Group 2, is given at the end of this bulletin.

THE SAN EMIDIO GRANT.

A hasty visit was paid to Muddy Creek and the San Emidio Grant. At the former place the formation is principally sandstone, and many fragments of gypsum are scattered on the slope of the hills. A spring of strong sulphur water is situated on the southern bank of the creek. The surface of the water in this spring is covered with sulphur, and the air is redolent with sulphuretted hydrogen. The taste of the water is nauseating in the extreme, and is said to act with severity on the bowels.

At the San Emidio Grant the writer followed the outcrop of a thin stratum of fossiliferous limestone from Muddy Creek in a southwesterly direction, and obtained several fossils, which were submitted to Dr. J. G. Cooper for examination, who classified them as follows:

Fossils Collected on San Emidio Grant between the Muddy and Lobos Creeks.

Crassatella collina, Con.	Pliocene, Miocene.
Glycimeris generosa, Gould	Living, Quaternary, Pliocene, Miocene.
Macoma secta, Con.	Living, Quaternary, Pliocene.
Neverita recluziana, Pet.	Living, Quaternary, Pliocene, Miocene.
Dosinia mathewsoni, Gabb	Miocene.
Macoma, n. sp.	
Tapes staleyi, Gabb	Pliocene.
Tapes, n. sp.	
Cryptomya californica, Gabb	Living, Quaternary, Pliocene, Miocene.

At Lobos Creek, on the San Emidio Grant, was observed a stratum of shells about 2 feet in thickness, and it appeared to be composed entirely of *Crassatella collina*. The formation dipped to the east of north, and at an angle of about 70°. The fossiliferous stratum rested on a light-colored shale, which was exposed higher up the creek. A large amount of bituminous matter had issued from the shale, accumulated in the creek, and, flowing down the creek-bed, had formed a layer of brea overlying the shelly stratum.

NATURAL GAS AND FOSSILIFEROUS FORMATIONS ON THE EASTERN SIDE OF THE SAN JOAQUIN VALLEY.

The wagon road from Sumner to the Rio Bravo ranch traverses a series of alluvial bluffs, which form the first bench of the eastern foothills. These foothills, where the Kern River enters the valley, are formed for the most part of soft Tertiary strata, which abut the granitic rocks of the Greenhorn Mountains. The Tertiary formation here is mainly friable sandstone, traversed by a few thin strata of sandy limestones and fossiliferous rock. The characteristic features of the formation are a large amount of quicksand and some beds of impure gypsum. In many of the bluffs beds of cobblestones and bowlders are exposed. From a bluff on the west side of Kern River, about 2 miles down the stream from the Rio Bravo ranch, is found a ledge of fossiliferous sandstone. On the south line of Kern River, a few miles eastward from the Rio Bravo ranch, near the contact of the Tertiary and the granitic rocks, several thin fossiliferous strata were noted. The surface of the hills is in some places covered with impure gypsum. From the top of what is locally known as Pyramid Mountain, at an elevation of 2,800 feet, is an extended view showing the line of contact between the granite and the sedimentary strata, the eastern margin of the latter being in places strewn with fragments of granite, which protrudes here and there through the softer formations. To the west and south nothing but sedimentary formations appear to be in sight. Near the top of Pyramid Mountain a ledge of fossiliferous rock crops out. This ledge also forms the summit of a neighboring elevation farther eastward, which is about 150 feet lower than Pyramid Mountain. Both these eminences are situated on the divide between Poso Creek and Kern River.

In 1891, Mr. J. Barker, who resided at the Rio Bravo ranch, discovered natural gas in a spring on his property in the center of Sec. 5, T. 29 S., R. 29 E., M. D. M., and he erected a small receiver in order to utilize the gas for illuminating purposes. He bored a 10-inch well about 300 yards east of the above-mentioned spring, which is situated on the south bank of the river, and probably 15 feet above the water's edge. The formation penetrated is a fossiliferous clayey sand. At a depth of 26 feet a flow of 8 miner's inches of mineral water, and some gas, was obtained. The temperature of the water was found to be 80° Fahr. The well was continued through a similar formation to a depth of 48 feet. Casing was then pushed down, and the water to the depth of 26 feet was shut off. When this was done, the gas and water forced their way up outside of the casing. A stream of not less than 2 miner's inches then flowed from the casing, and the well yielded a greater volume of gas than the spring in which the gas was first observed. At a depth of 48 feet a stratum of limestone was struck, a fragment of which contained a good specimen of *Solen rosaceus* of unusually large size. A partial analysis of the water from this well, made by Prof. E. W. Hilgard, was as follows:

	Grains to the gallon.
Sodium and potassium sulphate (Na_2SO_4 and K_2SO_4)	**22.99**
Common salt (Sodium chloride) ($NaCl$)	**197.00**
Sodium carbonate (Na_2CO_3)	**22.52**
Calcium and magnesium sulphate ($CaSO_4$ and $MgSO_4$)	**5.55**
Silica (SiO_2)	**5.21**
Total	**253.27**

The following fossils were obtained by the writer from the Tertiary formation in the vicinity of the Rio Bravo ranch, and they were afterwards submitted to Dr. J. G. Cooper for classification:

From Bluff on North Side of Kern River about Two Miles down the Stream from Rio Bravo Ranch.

***Conus californicus*, Hinds**	Living, Quaternary, Pliocene.
***Neverita callosa*, Gabb**	Miocene.
***Dosinia mathewsoni*, Gabb**	Miocene.
***Pecten discus*, Con.**	Miocene.
***Cerithium*, n. sp.**	
***Tapes staleyi*, Gabb**	Pliocene.
***Axinæa patula*, Con.**	Pliocene, Miocene.
***Cancellaria*, n. sp.**	
***Lunatia lewisi*, Gould**	Living, Quaternary, Pliocene.
***Nassa californica*, Con.**	

Meretrix tularana, Con.	Miocene.
Solen rosaceus, Cpr.	Living, Quaternary, Pliocene, Miocene.
Teeth of *Oxyrhina tumula*, Agassiz	
Teeth of *Oxyrhina plana*, Agassiz	
Vertebræ of some reptile's tail bones	

From Ravine near the Contact of the Granite and Tertiary Formation.

Tellina ocoyana, Con.	Miocene.
Dentalium, n. sp.	
Myorella, n. sp.	
Neverita callosa, Gabb	Miocene.
Arca microdonta, Con.	Pliocene, Miocene.

From various places on the South Side of Kern River on the Barker Ranch.

Solen rosaceus, Cpr.	Living, Quaternary, Pliocene, Miocene.
Tooth of *Oxyrhina plana*, Agassiz	
Cypricardia (?), n. sp.	
Agasoma (?), n. sp.	
Arca microdonta, Con.	Pliocene, Miocene.
Neverita callosa, Gabb	Living, Quaternary, Pliocene, Miocene.
Tellina ocoyona, Con.	Miocene.
Yoldia impressa, Con.	Living, Quaternary, Pliocene, Miocene.
Acila, n. sp.	
Leda, n. sp.	

From North Side of the Kern River on the Barker Ranch.

Pinna alamedensis, Yates	Miocene.

From Pyramid Mountain, about Five Miles North of the Rio Bravo Ranch.

Dentalium, n. sp.	
Axinæa patula, Con.	Pliocene, Miocene.
Pecten discus, Con.	Miocene.
Chione pertenuis, Gabb.	Miocene.
Crepidula grandis, Midd.	Quaternary, Pliocene, Miocene.

From Bluff near Pyramid Mountain.

Ostrea heermanni, Con.	Pliocene.

The specimens of marine mollusca collected by the writer near Kern River and at the San Emidio ranch, when classified by Dr. J. G. Cooper, were found to represent the following palæontological periods:

Thirty-three Species from Eastern Side of the San Joaquin Valley, near Kern River.

	No. of Species.	
Miocene	10	19 Miocene.
Miocene, Pliocene	4	
Quaternary, Pliocene, Miocene	1	
Living, Quaternary, Pliocene, Miocene	4	
Pliocene	2	5 Pliocene.
Living, Quaternary, Pliocene	3	
N. sp.		9

Nine Species from San Emidio Ranch on the Western Side of the San Joaquin Valley.

	No. of Species.	
Miocene	1	5 Miocene.
Pliocene, Miocene	1	
Living, Quaternary, Pliocene, Miocene	3	
Pliocene	1	2 Pliocene.
Living, Quaternary, Pliocene	1	
N. sp.		2

Dr. J. G. Cooper says: "It should be remarked that the proportions of species here given as extending downward to the Pliocene or Miocene strata are based on what was hitherto known of their vertical ranges, and cannot be always considered decisive, especially when only a few species are given. Late explorations tend to show that they are not ys separable in California, and they have therefore been lately combined under the name of Neocene. There is, however, good evidence, obtainable from large numbers of species, to show the relative age of the Tertiary strata, and good ones can always be separated from the Cretaceous or Eocene, here called Cret. B."

There are other places on the eastern side of the San Joaquin Valley, in Kern County, where natural gas has been found, notably in T. 29 S., R. 28 E., M. D. M.; and in the township named bituminous sandstone is exposed on the northern bank of Kern River. For further description of these localities the reader is referred to our VIIth Report, p. 67.

THE BUENA VISTA OIL AND ASPHALTUM DISTRICT.

The Buena Vista Oil and Asphaltum District is situated about 26 miles in a northwesterly direction from the Sunset Oil Wells. The Buena Vista oil territory comprises oil claims which are owned by the Standard Asphalt Company, the Buena Vista Oil Company, and others.

The Standard Asphalt Company.—The Standard Asphalt Company was incorporated in Bakersfield in 1892. This company has leased certain oil and asphaltum claims belonging to the Union Land and Oil Company of Georgia, the Columbian Oil Company, and J. Quirolo. The territory thus leased comprises about 1,480 acres in T. 30 S., R. 22 E.; also, 160 acres in T. 30 S., R. 21 E., and 240 acres in T. 31 S., R. 22 E., M. D. M. The company has also located thirty-seven or more oil and asphaltum claims in the vicinity of Asphalto. The territory leased by this company and the claims located by them are all situated within a radius of about 4 miles from the western terminus of the branch line of the Southern Pacific Railroad between Bakersfield and Asphalto. The property of the company at Asphalto consists of the oil and asphaltum claims located by them, the lease above mentioned, a plant for refining asphaltum, which is furnished with twenty-one kettles; also a boarding-house capable of accommodating about forty men, and a store-house of four rooms. The railroad track extends to the refinery.

The Buena Vista Company.—The property of this company consists of about 720 acres, in addition to territory leased from them by the Standard Asphalt Company, all in T. 30 S., R. 22 E., M. D. M. In May, 1893, the improvements of the Buena Vista Oil Company consisted of a boarding-house capable of accommodating about 20 men; an oil well 410 feet deep; another 92 feet deep; two dry wells, one of which is 204 and the other 202 feet deep. All these wells were bored by E. Rowe, of Stockton, in 1892. At one time 22 barrels of oil were daily pumped from the deepest well. In this well oil was struck at a depth of 392 feet, but it is said to have been shut off when the casing was lowered to a greater depth. This well was drilled "snug" to the casing, leaving the casing to cut its way for about half an inch. The well is cased with 5⅝-inch casing, consisting of ¼-inch screw pipe. The formation penetrated is said to be sand. The writer was informed that 23 feet of asphaltum was bored through at a depth of 345 feet. The 92-foot well was sunk in July, 1892. This is an 8-inch well, and is cased with No. 16 iron, single casing. This well yields three barrels of oil daily by baling. (See table of oil analyses at the end of this bulletin.) The Buena Vista Company store their oil in a 250-barrel tank. There are also some smaller tanks on the property of this company. A record of wells which were bored in this district prior to those herein mentioned will be found by referring to our VIIth Report.

Topography of the Buena Vista Oil District.—The oil claims of the Standard Asphalt Company and the Union Oil Company commence on the northern side of the railroad at Asphalto. From the railroad the ground slopes in a northerly direction toward a tier of low rolling hills, which stretch out into the San Joaquin Valley. Between the railroad and the rolling hills several prospect holes have been sunk in the drift to a depth of from 8 to 12 feet. Some of these holes show pulverulent, carbonaceous material, which is no doubt decomposed asphaltum. In a few of the holes asphaltum has been struck which is similar in appearance to that composing the extensive asphaltum beds lying to the south of the railroad track, as hereinafter described. The hills to the north of the railroad track are covered with alluvium, and no rocky strata are exposed. In one of the ravines which cut through these hills there are exudations of asphaltum of limited extent.

The asphaltum beds leased by the Standard Asphalt Company and those owned by the Buena Vista Company extend up the hillside in a southerly direction from the railroad track; amid these asphaltum beds there are seepages of heavy oil, which collects in shallow pits that have been dug in the asphaltum for that purpose. The tier of hills on which the asphaltum beds are situated are the foothills of the main chain of the Coast Range lying to the south of Asphalto. These hills are for the most part covered with alluvial soil, which sustains a scanty herbage during the spring; but in many places there is an abundant growth of greasewood and sagebrush. Although many plants grow in a mixture of asphaltum and sand, the *Eriogonum inflatum* appears to be the only one which flourishes while its roots actually penetrate the asphaltum.

Rocky Formations of Buena Vista Oil and Asphaltum District.—The formation most extensively exposed in this district consists principally of light-colored silicious shales, similar to those seen in the Sunset Oil District. The outcropping rocks, which represent the formations resting on the light-colored shales, are scanty and irregular; they consist mainly of a peculiar, porous, silicious rock of low specific gravity, bituminous sandstones, silicified sandstones, and clayey and sandy strata. The porous silicious rock contains marine diatoms. In some places these infusorial rocks are impregnated with bitumen, and in other places with salt, the exposed surface being frequently found to be whitened, apparently by the action of the weather. These diatomaceous rocks, like the light-colored shales on which they rest, contain a large amount of silica. Samples of these silicious rocks examined showed as follows:

Description of Specimen.	Percentage Insoluble in Acid.	Percentage of Silica Contained in Specimen.	Percentage of Silica Soluble in Sodium Carbonate.
Light-colored shale from Asphalto	97.7	92.0	17.5
Porous, bituminous rock, containing diatoms	78.0	~~98.0~~ 78.0	39.0
Diatomaceous rocks impregnated with salt (after ignition, 37 per cent of this specimen was soluble in water)	62.0	60.0	20.0

In these estimations small fractions are disregarded. A good exposure of these saline rocks can be seen in the northwest corner of Section 33, where a cañon extends in a northeast and southwest direction. In this cañon a crust forms on the surface of the saline rocks, and this crust appears to be composed principally of salt (NaCl). A short distance from the outcrop of the saline rock the side of the cañon is formed of decomposed soft sandstone, but no rock-exposures are to be seen which throw much light on the relation of the sandy and clayey formations. The loose sandy surface is in some places strewn with quartzose pebbles, fragments of silicious rock, and a few marine shells. These shells were examined by Dr. Cooper, who determined them to be:

Pecten deserti, Con.	Pliocene.
Ostrea attwoodi, Gabb	Pliocene.

About half a mile from Asphalto by trail, and much less in a straight line, there is a spring of warm mineral water (see table of water analyses) which yields inflammable gas and a little oil. The gas smells strongly of sulphuretted hydrogen. A short distance eastward from the spring there is an outcrop of bituminous sandstone, which is much eroded and weatherworn. The greater portion of the hills in this vicinity is covered with what appears to be decomposed sandstones, through which the winter rains have cut deep ravines. In many places there are seepages of bituminous matter and outcropping ledges of asphaltum. In Section 27, as hereinafter described, the exposed formation is traversed by numerous veins of pure asphaltum. To the northwest of the boarding-house of the Buena Vista Oil Company, asphaltum has flowed down the hillside, but it is so eroded and weatherworn that it appears like the ruins of a lava stream. A few outcropping rocks of coarse sandstone show a strike of west of north by east of south; their dip is indeterminable, but they evidently stand at a great angle. A short distance farther westward, light-colored porous rocks make their appearance. Following the strike of the formation, the character of the debris covering the hills and an occasional outcropping ledge of rock evidence the proximity of the sandstone and the porous diatomaceous rocks. The sandstones are frequently oil-soaked, and seepages of maltha can be seen in almost every cañon. These features warrant the conclusion that the source of the oil and maltha is at or near the contact of the sandstone and the light-colored porous rocks. In one place a coarse sandstone and fine conglomerate can be seen in contact with the light-colored porous rock. The strike is east of south by north of west.

About 1½ miles west of Asphalto, in the northwestern portion of Section 20, there is an escarpment of light-colored sedimentary strata, some of which are bituminous. This escarpment rises abruptly for about 100 feet; the dip of the strata appears to be east of south and at an angle of about 25°. Some of these strata are interspersed with fragments of silicious shale, which resembles the silicious shale seen farther to the westward. It appears, therefore, that the whole cliff is of more recent formation than are the light-colored silicious shales. At the base of the cliff a vein of very pure asphaltum is exposed. To the southward of the strata forming this cliff, porous silicious shales are seen, but as investigation is made in a southerly direction across the strike of the formation, light-colored shales are found to lose their porous character, and appear to be indurated with silica.

The average strike of these silicious shales is N.W.W. by S.E.E. No exposures were found where the dip could be determined in a satisfactory manner, but the formation evidently stands at a great angle. In a few places there are weatherworn masses of impure limestone, but they do not appear to be in place. Still farther to the southward the light-colored shale is covered with alluvial soil, which affords excellent pasture during the spring. These rolling grazing lands extend to the Santa Maria Mountains, as the dominant ridge of this portion of the Coast Range is called. These mountains appear to be composed of metamorphosed sedimentary strata; at least, the writer saw no other rock exposed at the point where he ascended the divide, and one specimen obtained from this locality was bituminous. The dip of this formation is a little east of south, and at an angle of 25°.

THE SUPERFICIAL ASPHALTUM BEDS AT ASPHALTO.

The asphaltum deposits at Asphalto are found under two conditions: First, as superficial beds of impure asphaltum; secondly, as veins of asphaltum in the country rock.

As before mentioned, the superficial beds are situated to the south of the railroad track at Asphalto. The first bed examined covers an area of probably seven acres, and extends from the store of the Standard Asphalt Company to the white heap at the northern base of the hill, seen in the accompanying photograph. The asphaltum rests partly on sandy and clayey drift, and partly on a white calcareous sand, which has been struck in some pits that have been sunk through the asphaltum to a depth of about 12 feet. This bed of asphaltum constitutes the northern portion of a much larger bed, the southern portion of which was still reserved by the Buena Vista Oil Company in May, 1893. From the asphaltum bed which has been leased by the Standard Asphalt Company, large quantities of crude asphaltum have evidently been removed. The crude asphaltum varies in quality; some of it is brownish in color, and resembles ironite; it is frequently pulverulent and more or less mixed with earthy matter. The best asphaltum in these superficial beds lies near the surface; in some places it forms a stratum varying in thickness from a few inches to about two feet or more. This stratum principally consists of a dull-black, compact asphaltum, but some of it possesses a pitch-like luster, and here and there it is rendered viscous by fluid petroleum.

About 200 paces south of their store, the Standard Asphalt Company have dug a trench across the asphaltum bed leased from the Buena Vista Oil Company. This trench, which is a little more than 100 yards in length, has been dug to the depth of from 6 to 12 feet, in order to test the thickness and quality of the asphaltum. This prospect work has shown that the best asphaltum is near the surface, where it varies from 6 inches to 2 feet in thickness. Beneath this upper stratum it is very impure and rotten, and is intercalated with wash from the mountain. In some places the trench cuts through small veins of asphaltum, which penetrate the earthy material and give evidence of the fluidity of the asphaltum at the time of its deposition. At its eastern end, this trench cuts into the hillside and shows a sandy formation, which is not hard enough to be classed as sandstone; some of the sand is fine and some coarse, and contains small pebbles; no stratification is to be seen. In some places the sand is cemented with petroleum. A short distance to the eastward of the white heap shown in the photograph of Asphalto, a series of irregular pits have been sunk. These pits show a superficial stratum, about 2 feet in thickness, of fairly good asphaltum, beneath which, to the depth of about 20 feet, the formation is similar to that in the lower portions of the trench previously described. The greater part of the superficial asphaltum has been removed from the surface of the bed which is leased by the Standard Asphalt Company. At the time of the writer's visit there were heaped up or strewn on the surface of this bed 100 tons or more of fairly good asphaltum. The holes caused by mining were filled with heavy oil, or with water, the surface of which was covered with floating oil. The asphaltum beds, which in May, 1893, were still reserved by the Buena Vista Oil Company, commence a little more than 1,000 feet to the southward of the store belonging to the Standard Asphalt Company.

At that date the superficial asphaltum had not been removed from these beds, and a pit, in which much heavy oil had collected, showed a superficial stratum of about 4 feet in thickness, of fairly good asphaltum. Beneath it is sand, impregnated with heavy oil. Southward from the tank seen in the photograph a trench, which has a northerly and southerly direction, has been cut to a depth of from 3 to 12 feet. This trench is about 250 feet in length and penetrates asphaltum and sand soaked with heavy oil. The oil accumulates in the bottom of this trench and sluggishly flows through a pipe into a tank. Another ditch branches off in a southeasterly direction from the one last described, and shows that the asphaltum at that point is about 2 feet in thickness, and that it rests on oil-soaked sand. This plot of asphaltum, which has been reserved by the Buena Vista Oil Company, probably covers an area of about six acres. Other asphaltum beds extend to the westward of the roadway, which runs in a southerly direction from Asphalto, and to the westward of the boarding-house of the Buena Vista Oil Company.

These asphaltum beds are evidently much more ancient than those farther down the hill, and much of the asphaltum is of poor quality. The general trend of these ancient asphaltum beds is northwesterly and southeasterly, and they appear to extend along the contact of the sandstone and light-colored shale. The shale has a general strike of north of west by south of east, and evidently stands at a great angle. In some places these asphaltum beds show evidence of having been on fire, and masses of clinker have been formed. This clinker is locally called "coked asphaltum," a sample of which showed 39.1 per cent of carbonaceous matter. There must be more than ten acres covered with this ancient asphaltum on the land of the Buena Vista Oil Company, all of which is situated on the hills overlooking Asphalto.

Attempts to Refine Asphaltum.—Several years ago an experimental attempt to refine asphaltum was made by the Buena Vista Oil Company. What remains of their plant consists of three kettles, 3x8 feet, by 20 inches deep; a tank, and four kettles not set up. In May, 1893, the tank and three of the kettles were full of oil, and piled up near the kettles were many boxes of refined asphaltum. The asphaltum appeared to contain much oil, for it had partly melted under the heat of the sun.

Although there is a large amount of impure, crude asphaltum in these beds, only a small portion is sufficiently pure to pay for mining and refining by the methods now employed. It is possible, howev that the impure, crude asphaltum may be of value as bituminous roc

THE ASPHALTUM VEINS IN THE BUENA VISTA DISTRICT.

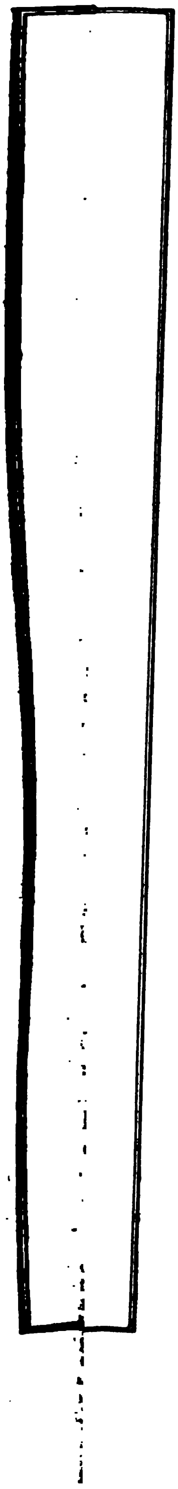
The principal working from which asphalt was being mined at t time of the writer's visit to this district, is near the N.W. corner of t S.W. ¼ of Sec. 27, T. 30 S., R. 22 E., M. D. M., and is marked as Fla No. 1 in the accompanying sketch-map. It consists of a shaft, wit drifts connected therewith. This shaft is about 40 feet deep, and ha been sunk on a vein of asphaltum which shows a thickness of 8 fee and dips about 15° west of north. The asphaltum is of a high grade, i black, lustrous, and breaks with a ready cleavage. At the depth of 1 feet the vein widened and was drifted on for 15 feet 20° east of north, 4 feet 70° east of north, and 18 feet 70° west of south. At the end of th 18-foot drift the vein pinched, and an inclined shaft was sunk thereo 6 feet. At the bottom of the inclined shaft the vein again widened, and was drifted on for about 7 feet in a northwesterly direction along its strike, the foot wall being light-colored clay, and the hanging wall a light-colored, friable sandstone. The course of the vein then turned until it showed a strike of 44° east of south, and the foot wall changed from clay to coarse sand. At the end of this drift the angle of the dip greatly increases, the vein pinches to a width of about 4 inches, and the light-colored clay comes in again as a foot wall. A short distance from the end of the drift the vein has been stoped out to the depth of about 12 feet below the floor. In the bottom of the stope the vein widens to about 4 feet, showing about 2 feet of pure black asphaltum, which is separated from the walls by about a foot of dull and somewhat pulverulent asphaltum.

Passing to the bottom of the shaft, a lower vein of asphaltum about 2½ feet thick is seen dipping about 5° west of north, at an angle of about 45°. The foot wall is light-colored clay with streaks of gypsum, and the hanging wall is sandy clay. The drift penetrates the hanging wall, and the following strata are passed through:

Sandy clay	7 feet.
Hard and calcareous stratum	6 inches.
Sandy clay	7 feet.
Loose sand	4 inches.
Sandy clay	2 feet.
Asphaltum	6 inches.

The drift terminates in light-colored, friable sandstone. This 6-inch vein is, no doubt, the same vein which is mined in the upper level; in the lower level the vein dips 25° east of north.

In mining this asphaltum, holes are bored in the clay to the depth of 2½ feet, with augers. Each hole is charged with a stick of No. 2 giant powder. Three such charges usually move or loosen a block of clay 4 feet wide, 6 feet high, and 2 feet thick. The sand is mined with picks, but the hard streaks sometimes require drilling. When the work can be so adjusted as to allow time for the smoke to clear, a good effect is obtained with two holes and the use of Judson powder. When this powder is used, one hole is bored in the top and the other in the bottom of the face of the drift. The bottom hole is sprung with half a stick of giant powder, and is then loaded with from one to two quarts of Judson



powder; the top hole is loaded with a stick of giant powder. The fuse used for the bottom charge is a little shorter than that used for the upper charge, so that the Judson powder is exploded first.

In the formation hitherto encountered, which is about half clay and half sand, two men can drift from 5 to 6 feet a day, if the wheeling and hoisting are done by others. The clay is dry and stands without timbering, but the sand is timbered and lagged on the roof and sides of the drift. As may be supposed, mining in such a formation is not very destructive to tools. Two men picking in the sand will dull four or five picks daily, but in the clay one pick will last a man a week or more. The asphalt splits with ready cleavage, and is easily mined. At the time of the writer's visit a second shaft was being sunk about 35 feet from the one described.

About 200 yards north of the main shaft a broad band of light-colored clay stretches across the country, and has a strike of 53° west of north (see sketch-map). Extending eastward from this shaft toward Station 2 are shallow workings and prospect holes. These appear to have been sunk on the outcropping edge of the lower vein of asphaltum which was mined in Shaft No. 2. In these workings the stratum of asphaltum is well exposed, and dips somewhat irregularly between 15° and 25° east of north, at an angle of from 45° to 55°. The average width of the vein is from 3 to 4 feet, and much of it is good, bright, black asphaltum. In one of these excavations a tunnel has been run into the hill for about 40 feet in a northeasterly direction. The formation penetrated is light-colored clay and soft friable sandstone, dipping 25° east of north, at an angle of about 50°. It is probable that this excavation has been made on a fold in the strata, for although, as above noted, the tunnel which runs into the hill from the northeast side of the excavation shows a dip to the east of north, the strata on the south side of the excavation dip 2° west of north, at an angle of 50°. About 65 feet to west of Shaft No. 2, outcroppings of the vein are found. The vein at this point shows a strike of 68° west of north and dips 22° east of north, at an angle of about 70°. At Station 2 there is a good exposure of a vein of asphaltum, dipping 23° east of north, at an angle of 50°. The strike of this vein would, if extended in a southwesterly direction, carry it across the ravine in which the already described workings are situated; and following along the strike of the vein for a short distance in a northwesterly direction across the ravine, a shaft about 10 feet deep is reached, which shows a vein of asphaltum about 3 feet in thickness. Crossing the roadway and a ravine which leads in a southeasterly direction, superficial excavations are found showing asphaltum mixed with sand and clay. On the eastern side of the ravine there are three tunnels, which are marked, respectively, on the accompanying sketch-map as tunnels *a*, *b*, *c*.

Tunnel *a*, which is situated about 20 feet above the bottom of the ravine, has been run in a southwesterly direction. The formation penetrated dips 20° west of south, at an angle of about 20°, and is as follows:

Light-colored clay	20 paces.
Asphaltum	2 feet.
This asphaltum is partly a pure black variety, and partly light and powdery and mixed with clay.	
Fine, light-colored sand	7 paces.
Light-colored clay and sandy clay traversed with streaks and pockets of asphaltum	15 paces.
One of these pockets was 2 feet thick, 4 feet wide, and extended from the floor to the roof of the tunnel.	

Reddish-brown sand	20 paces.
Light colored, clayey sand, with streaks and pockets of reddish asphaltum	20 paces.
Light-colored sand, some of which was saturated with oil	2 paces.

At the end of the tunnel there is a seepage of heavy oil.

Tunnel *b* was commenced about 20 feet farther down the side of the ravine than tunnel *a*, and is about 20 paces distant therefrom in a northwesterly direction. This tunnel has been run into the hill for about 50 paces in a southwesterly direction. The formation is similar to that observed in the upper tunnel, but the dip is a little more westerly. At the mouth of the tunnel there appears to be an irregular vein of asphaltum, but a winze sunk thereon about 7 feet shows only a few seams of asphaltum of no great width traversing a light-colored clay.

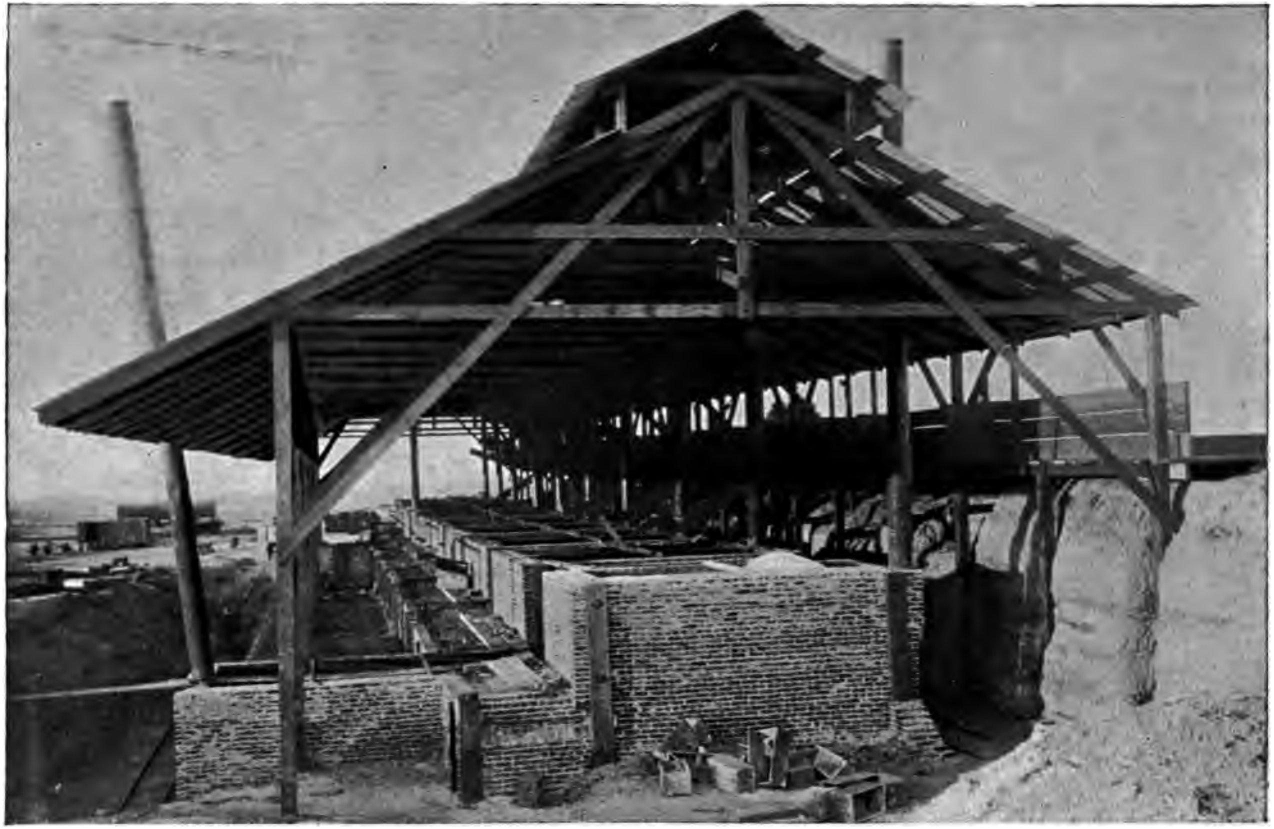
A short distance southeast of tunnel *b* an open cut shows a disturbed vein of asphaltum about 2 feet in width, and irregular masses of asphaltum spreading out therefrom. The inclosing rocks, which dip 30° east of south, at an angle of about 40°, are light-colored, sandy clay. This formation is penetrated by tunnel *c*, which has been run nearly in the direction of the dip, and is as follows:

Light-colored sandy clay, with asphalt	7 paces.
Reddish-brown sand	15 paces.
Light-colored clay, with seams of gypsum	7 paces.

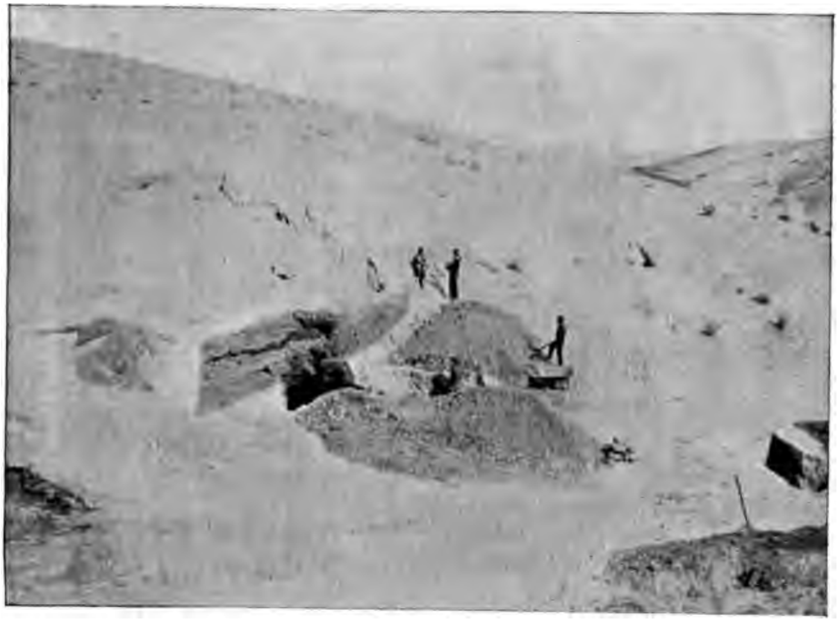
About 35° west of south from tunnel *c* an open cut shows an irregular-shaped mass of asphaltum, inclosed in soft brown sandstone, which is faulted in places, and a fissure occasioned thereby is filled with asphaltum. This is somewhat softer than that obtained from the shafts, and the heat of the summer's sun had evidently been sufficient to melt it. At Station 5 the dip of the soft brown sandstone is 60° east of north, and a fissure, having a direction of 55° east of north, has been filled with very pure asphaltum, forming a vein from 4 to 5 feet in width. The fissure is nearly vertical, and the vein has a slight pitch to the northwest.

A few yards east of south from Station 5 there are open cuts in a soft bituminous sandstone, which show straggling veins of asphaltum of no great thickness. On the western side of the principal ravine, at Station 6, the formation dips 35° west of south, at an angle of about 60°. A vein of high-grade asphaltum of about one foot in width is here exposed in an open cut. Both the head walls and foot walls are formed of light-colored clay, which is seamed with gypsum. About 20 yards west of Flag B a soft, dark-brown sandstone is exposed, which becomes grayish on the outside by exposure to the air. At Station 7 are bituminous shales, which become almost white by exposure; these shales dip 85° west of south, at an angle of about 80°. Between these shales and the soft brown sandstone is a soft silicious stratum, containing marine diatoms, and saturated with bituminous matter. The surface of this silicious stratum is white, and appears to have been bleached by exposure. Both the soft silicious stratum and the sandstone have suffered greatly by erosion, especially along the contact of the shales and the soft silicious rock, where a gulch has been formed, which has a course of from 20° to 40° west of north and east of south. The dark color of the material forming these shales, silicious rocks, and sandstones is evidently occasioned by bituminous matter.

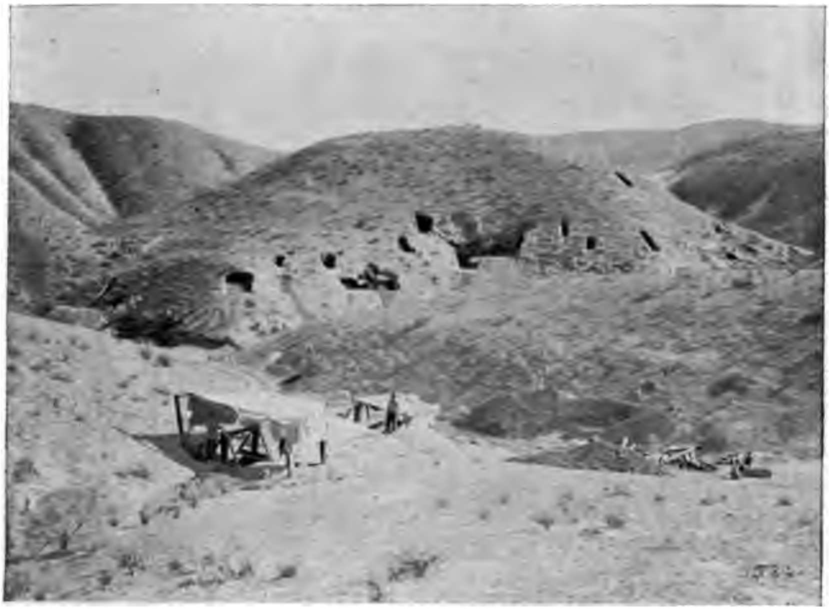
At Station 8, an open cut about 6 feet deep shows the dip of the



Interior of Asphalt Refinery at Asphalto, Kern County.



Asphalt Mine, showing Vein of Asphalt. Buena Vista District, Kern County.



Asphalt Mines in Buena Vista District, Kern County.

formation to be 40° east of south, and shallow cuttings between Stations 8 and 9 show asphaltum "prospects"; but the exposures are not sufficient to determine either the dip or strike.

At Station 9, a soft, dark-colored sandstone, similar to that near Station 7, is exposed, having a strike of 60° west of north, and dipping southwesterly at an angle of about 70°. At Station 10, an open cut shows a body of asphaltum about 4 feet across, which has been bent upward and folded on itself, apparently by a flexure in the formation.

At Station 11, a pit about 8 feet deep shows a disturbed formation of sandy clay and asphaltum. The probable strike is 75° west of north, dip northeasterly, and at a great angle.

At Station 12, an open cut about 12 feet deep shows several strata of impure asphaltum, which vary in thickness from 1 inch to about 1 foot. The asphaltum is intercalated by thin strata of light-colored clay, sand, and pebbles. One of the uppermost strata, which is composed of dark-colored sand, is fossiliferous and contains fresh-water shells. The pitch of the fossiliferous stratum is 80° east of north, and at an angle of about 50°; the fossiliferous stratum rests upon impure, sandy asphaltum, on sand impregnated with bituminous matter. Specimens of these fresh-water shells were submitted to Dr. Cooper, who found them to be:

Anodonta nuttaliana, Lea	Living.
Carinifex newberryi, Lea	Living.
Pomatiopsis intermedia, Tryon	Living.

At Station 13 a 25-foot tunnel has been run into the hill, and cuts a vein of powdery asphaltum, more or less mixed with clay and sand. There are also several open cuts and shallow workings between Flags D and C, which show the strike of the formation to be 65° east of south, and the dip 25° east of north, at an angle of about 40°. In two of these cuts a stratum of calcareous clayey sandstone is exposed, which contains numerous small fresh-water shells similar to those seen at Station 12. In one of these openings the bones of mammals were found beneath the impure asphaltum which underlies the fossiliferous stratum in this locality.

A few yards westward from these workings a line of open cuts shows a vein of asphaltum similar to the one already noted between Flags D and C, but the dip is 35° west of south at an angle of 65°. At Station 15, about 250 yards to the southwest of Station 13, and in the same ravine, there is a tunnel a few feet in length and a shaft about 12 feet deep. The formation penetrated is dark-colored, soft sandstone and sandy clay. In the tunnel a vein of high-grade asphaltum is exposed, standing nearly vertical and having a strike of 10° east of south. At Station 16, between Flags B and E, two open cuts show a mass of asphaltum about 2 feet in thickness, and some heavy oil. At three places between Stations 16 and B, open cuts show irregular veins of asphaltum, which vary in thickness from that of a few inches to about 2 feet. The asphaltum is more or less mixed with clay and sand.

Remarks on the Asphaltum Veins.—The asphaltum veins herein described may be divided into two orders: those having a strike and dip dissimilar to that of the rocks inclosing them, and those having a strike and dip similar to that of the inclosing rocks. The asphaltum veins of the first order are no doubt dikes of asphaltum, which occupy fissures in what appear to be rocks of late Tertiary formation. The genesis of the asphaltum veins of the second order is more dubious; some of the veins may be dikes filling fissures formed between the contact planes of upheaved strata, or they may have been formed as subaqueous exudations. The asphaltum has a specific gravity of about 1.10, and even if it were less, assuming that it exuded beneath water, its viscosity would tend to keep it submerged. An interesting feature of this locality is the diversity in the direction of the dip of asphaltum-bearing strata within comparatively small areas, although the prevailing dip appears to be northeasterly. As the purport of this article is merely to describe the geological conditions under which these asphaltum veins occur, it is unnecessary to theorize.

This recent discovery of veins of asphaltum appears the more important when we remember that formations of similar geologic age to those at Asphalto can be traced along the foothills on the western side of the San Joaquin Valley, and it is hardly likely that these veins of asphaltum are confined to the vicinity of Asphalto. The heavy mantle of alluvium covering the western foothills of the San Joaquin renders prospecting in these formations difficult, but the rapid erosion which takes place during the rainy season will probably, from time to time, expose outcropping veins of asphaltum, which, in view of the recent discoveries at Asphalto, it would be well to investigate.

THE REFINERY OF THE STANDARD ASPHALT COMPANY.

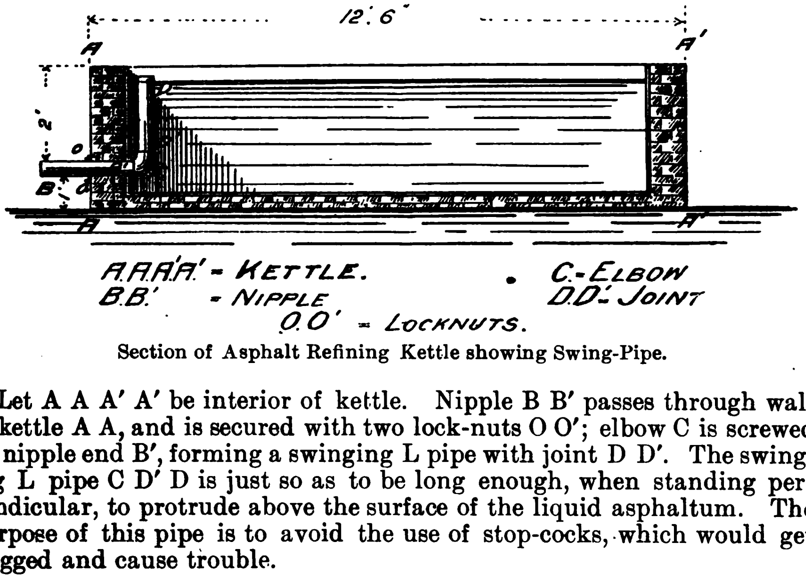
As before mentioned the refinery belonging to this company is situated at Asphalto, and consists of a plant furnished with twenty-one refining kettles. The refining kettles, as shown in the accompanying photograph, are set nineteen in a row, and each is about 12½ feet long, 5 feet wide, and 3 feet deep. They are made of steel, and are surrounded by brickwork; they are suspended by angle-iron flanges, which are riveted to the kettles, the free limbs of the angle-irons resting on the brickwork. The fireplaces are situated below the level of the kettles, and about 5 feet in front of them. Dry, crude asphaltum and asphaltum refuse are used as fuel, and the flames therefrom pass over a fire-arch before reaching the bottom of the kettles. Iron pipes are used as grate-bars, the ends being left open so as to permit the air to circulate through them, and by this means the bars resist the heat, which is very great, for the melted fuel runs through between the bars, and burns in the ash-pit. The refining kettles are arranged in pairs, and each pair is furnished with a separate smokestack. The refining kettles are connected with kettles for receiving the refined asphaltum, and each of the receiving kettles is furnished with a smokestack.

The crude asphaltum is stacked up on a charging floor, which is situated 4 or 5 feet above the level of the refining kettles and a few feet distant therefrom. From this floor the asphaltum is fed into the kettles by chutes. A little heavy oil is then added to the asphaltum to assist its liquefaction. When 90 per cent asphaltum is refined, a kettle is charged, boiled, and emptied in twenty-four hours. The asphaltum is considered sufficiently refined when it cools and sets quickly as a hard, brittle substance possessing a high luster. The quality of hardness is only required to enable the asphaltum to be shipped, for it has to be fluxed with liquid petroleum previous to use. This refinery is said to have a capacity of 20 tons every twenty-four hours, when 90 per cent asphaltum is refined. The time consumed by the operation of refining naturally varies according to the richness of the crude material. The lower the grade of the crude asphaltum, the longer it takes to refine it.

Samples containing sandy impurities are the most easy to refine, and those containing clayey matter are the most difficult. In refining a low-grade asphaltum, as soon as the crude material becomes sufficiently liquid to allow the heavier impurities to settle, the liquid asphaltum is transferred to a clean kettle, wherein the process is continued. The refined material is drawn off through tap pipes ("swing pipes"), and it is conducted by a gutter into large receiving kettles.

The receiving kettles are 17 feet long, 6 feet wide, and 4 feet deep; and each of them hold about 15 tons of asphaltum. In these the asphaltum is kept at such a temperature that it will flow readily when poured. From the receiving kettles the asphaltum is drawn off into a swinging kettle, which holds about 65 gallons. This is set on wheels, and is pushed along a track, by the side of which wooden boxes destined to hold about 110 pounds of asphaltum, are arranged. The boxes are filled by pouring from the swinging kettle.

The "swing pipe" before referred to, which is used to draw off the refined asphaltum, is constructed according to the accompanying drawing.



Section of Asphalt Refining Kettle showing Swing-Pipe.

Let A A A' A' be interior of kettle. Nipple B B' passes through wall of kettle A A, and is secured with two lock-nuts O O'; elbow C is screwed on nipple end B', forming a swinging L pipe with joint D D'. The swinging L pipe C D' D is just so as to be long enough, when standing perpendicular, to protrude above the surface of the liquid asphaltum. The purpose of this pipe is to avoid the use of stop-cocks, which would get clogged and cause trouble.

In the process of refining it is found best to commence with a slow fire and gradually increase the heat until a temperature of from 250° to 300° Fahr. is attained. Constant stirring is needed to prevent the sediment from burning, which would soon destroy the kettle. Before "tapping" the asphaltum the fire is drawn and the liquid asphaltum is allowed to stand for an hour or more so the impurities may settle. The "swing pipe" is then lowered and the liquid asphaltum is run out. The refuse is valuable as fuel, and could also be utilized as bituminous rock. It is used with good effect to line tanks and reservoirs. When twenty kettles are in operation ten men are required for each shift. This refinery was completed March 1, 1893. The first run was made on 300 tons of crude asphaltum from the superficial asphaltum beds leased by the Standard Asphalt Company, and about 100 tons of refined asphaltum were produced.

The higher grades of crude asphaltum are not only the most easily refined, but they are the most easy to mine and handle. They fracture readily, and can be "blocked off" with drift bars and picks. The tough, oily varieties of asphaltum have to be mined with a hot spade, and cut with ax-shaped mattocks and picks; heavy charges of powder are also required.

The cost of working 60 per cent crude asphaltum is figured at about $10 a ton, inclusive of mining and all expenses. When the impurities are of a sandy nature it is said that 30 per cent crude asphaltum can profitably be worked, and with clayey impurities 40 per cent. With regard to the grade of asphaltum which could be worked with profit, the limit would be controlled by the market price of refined asphaltum. The writer is informed that during 1893 the market price for refined asphaltum averaged $25 a ton f. o. b. at Asphalto.

The following extracts from the records of the Standard Asphalt Company have been courteously placed at the disposal of the California State Mining Bureau:

Comparative Analyses of Trinidad Pitch Lake Asphalt and Standard Asphalt from Bakersfield, California.

	California. Sample H, Crude from Mine.	California. Sample H, Refined.	Pitch Lake. Average.	Pitch Lake. Best.
Specific gravity	1.132	1.240	1.3857	1.3771
Softening temperature, F.	180 degrees.	150 degrees.	190 degrees.	183 degrees.
Flowing temperature, F.	220 degrees.	180 degrees.	205 degrees.	198 degrees.
Inorganic matter	9.57 per cent.	9.77 per cent.	35.66 per cent.	35.48 per cent.
Bitumen soluble in CS.	85.49 per cent.	90.16 per cent.	56.29 per cent.	57.47 per cent.
Bitumen soluble in ether	69.98 per cent.	86.45 per cent.	41.43 per cent.	41.59 per cent.
Percentage of total bitumen soluble in ether	81.85 per cent.	95.88 per cent.	73.60 per cent.	72.37 per cent.

"The above analyses of California asphalt were made by G. Q. Simmons, Sedalia, November 8, 1893. Those of Pitch Lake asphalt were made by Clifford Richardson, Washington, D. C., and the results are to be found in his report of 1892, page 114. In the case of the Pitch Lake petroleum, naphtha was used instead of ether."

The following tests were made by H. Stillman, Engineer of Tests to the Motive Power and Machine Department at Sacramento (S. P. Co.):

Asphalt.	Ash.	Soluble.	Insoluble.
Trinidad	1.5 per cent.	46.30 per cent.	52.20 per cent.
Cuban	2.8 per cent.	44.25 per cent.	52.85 per cent.
Asphalto	6.5 per cent.	59.55 per cent.	33.95 per cent.

"In the above, the Trinidad represents the imported asphaltum. The proportion of ash shows the amount of foreign matter, dirt, and sand contained. Of the organic matter, the proportion insoluble in petroleum spirit may be considered as pigment in a paint or varnish made from the same, while the proportion soluble in spirit express the pure asphaltum together with hydrocarbon oils or petroleum existing in the rock.

"The nature of paint made from the product (especially as to drying properties) will depend to a certain extent on the quantities of petroleum oil present. This could only be determined by continued process, requiring more of sample than at hand.

"Some idea of this may be obtained from the results of combustion:

	Soluble Hydrocarbon.	Fixed Carbon.	Ash.
Trinidad	77.15 per cent.	22.7 per cent.	0.15 per cent.
Cuban	70.20 per cent.	27.0 per cent.	2.80 per cent.
Asphalto	81.40 per cent.	12.1 per cent.	6.50 per cent.

"Proportion of volatile to fixed carbon would express their value as referred to in the above." * * *

Two samples analyzed by W. B. Potter, of the St. Louis Sampling and Testing Works, showed:

Asphalt from Asphalto.	Percentage of Asphaltum.
No. 1	88.90 per cent.
No. 2	85.32 per cent.

The manager of the Standard Asphalt Company informed the writer that the crude asphaltum, as it is mined from the asphaltum veins now being worked at Asphalto, averages 75 per cent of asphaltum.

BITUMINOUS FORMATIONS IN KINGS COUNTY.

After leaving Asphalto the writer visited Tar Cañon, in Kings County. It is said that bituminous formations extend through the foothills between Asphalto and Tar Cañon for a distance of more than 100 miles. The northern entrance to Tar Cañon is at an altitude of 1,000 feet. In this cañon there are seepages of heavy tarry oil, which in one place has formed a small quantity of asphaltum. The strata yielding the oil are somewhat metamorphosed shales and sandstones, and constitute a ridge, which rises, in one place, to an altitude of more than 2,000 feet. The shales exposed on the northern slope of this ridge are grayish, and become light colored on exposure; but they exhibit a different physical appearance to that shown by the light-colored shales which yield the heavy oil north of Coalinga. They appear to be unfossiliferous, and dip 10° east of north, at an angle of about 75°. The rock exposures on the northern slope and summit of this ridge show that these shales rest conformably on thick strata of sandstone and calcareous conglomerate.

From the upper strata of the sandstone the writer obtained a few fossils, which were classified by Dr. J. G. Cooper, as follows:

Dosinia conradi, Gabb	Miocene.
Ostrea titan, Con.	Miocene.
Ostrea bourgeoisi, Remond	Pliocene.
Pecten discus, Con.	Miocene.

As this collection contained a preponderance of Miocene fossils, Dr. Cooper referred the strata containing them to the Miocene group. Some of the strata of sandstone and conglomerate underlying the strata from which these fossils were obtained must at one time have been highly fossiliferous, but the metamorphism to which they have been subjected prevents the identification of the fossils they contained.

The ridge referred to appears to be separated from the main Coast Range by faulting and erosion. On following in an easterly direction the prevailing dip seems to be more easterly, and at a somewhat less angle than that in Tar Cañon. In some places in the eastern portion of the ridge, the strata appear to have been subject to contortion. This appearance, however, as seen at a distance, may, perhaps, be exaggerated by the manner in which the strata have been eroded. The formation exposed on the southern slope of this ridge shows strata of soft sandstone and sandy shales, aggregating a thickness of about 700 feet. To the northward and at the foot of this ridge, the formation is soft blue sandstone, the dip of which appears to be rather more easterly and at a somewhat less angle than that of the strata forming the ridge. From the blue sandstone the following fossils were obtained:

Chione gnidia, Sowby	Living, Pliocene.
Crepidula grandis, Midd.	Quaternary, Pliocene, Miocene.
Macoma edulis, Nutt.	Pliocene, Miocene.
Pinna venturensis, Yates	Pliocene.
Arca microdonta, Con.	Pliocene, Miocene.
Scutella gibbsi, Rem.	Pliocene, Miocene.

It is apparent that the fossils obtained from the blue sandstone show a more recent age than that indicated by the fossils collected at Tar Cañon.

The Kettleman Plain.—The Kettleman Plain is really a valley lying between the ridge of hills among which Tar Cañon is situated and a range of low hills which, on the northward and eastward, separate the plain from the main valley of the San Joaquin. The center of the Kettleman Plain is at an altitude of 500 feet. A reconnoisance of these hills showed that their more elevated portions are formed of soft blue sandstone, and their summits rise to an altitude of about 1,000 feet. The summits of these hills present a rounded, undulating appearance, while their sides are furrowed by narrow gulches and ravines deeply cut into the comparatively recent formations. At the summit of these hills the strata dip from 10° to 35° west of south and at an angle of something less than 30°. In the cañons leading to the westward, the direction of the dip of the formation averages about 25° west of south, and the angle of inclination varies from 25° to 35°. Near the summit of these hills, the blue sandstone on which the formations rest is interstratified with a few calcareous and fossiliferous strata. The following fossils were obtained therefrom:

Acila castrensis, Hinds	Living, Pliocene, Miocene.
Arca microdonta, Con.	Pliocene, Miocene.
Cardium meekianum, Gabb	Pliocene, Miocene.
Galerus diegoanus, Con.	Living, Pliocene, Miocene.
Galerus filosus, Gabb	Pliocene, Miocene.
Lutricola alta, Con.	Living, Pliocene, Miocene.
Macoma inquinata, Desh.	Living, Pliocene.
Mya arenaria, Linn.	Living, Pliocene.
Ostrea bourgeoisi, Remond	Pliocene.
Pseudocardium gabbi, Remond	Pliocene, Miocene.
Solen rosaceus, Carp.	Living, Pliocene, Miocene.
Standella falcata, Gould	Living, Pliocene.
Tapes staleyi, Gabb	Pliocene.
Balanus estrellanus, Con.	Miocene.
Scutella gibbsi, Remond	Pliocene, Miocene.

This collection may be classified in the order of their upward vertical ange, as follows:

Miocene	1	10 ranging back to the Miocene epoch.
Pliocene, Miocene	5	
Living, Pliocene, Miocene	4	
Pliocene	2	5 Pliocene.
Living, Pliocene	3	

As these hills seemed to offer a chance of obtaining some information as to the character of the more recent strata, which may reasonably be supposed to underlie the San Joaquin Valley, a cañon was selected and observations were made from which the sketch marked "Section of Tertiary strata in Kettleman Hills," and which accompanies this article, was drawn. The most interesting formation exposed in the Kettleman Hills is a sandy calcareous stratum, which is marked on the accompanying sectional sketch as Station No. 4, and contains fresh-water shells; but the fossiliferous portion is of no great thickness. The specimens of fresh-water shells obtained from this locality were classified by Dr. J. G. Cooper, as follows:

Anodonta decurtata, Con.	Pliocene.
Anodonta nuttaliana, Lea	Living, Quaternary, Pliocene.
Amnicola turbiniformis, Tryon	Living, Quaternary, Pliocene.
Carinifex newberryi, Lea	Living, Quaternary, Pliocene.
Goniobasis occata, Hinds	Living, Quaternary, Pliocene.
Margaritana subangulata, Cooper	Quaternary, Pliocene.
Physa costata, Newcomb	Living, Quaternary, Pliocene.
Planorbis tumens, Carp.	Living, Quaternary, Pliocene.
Sphærium dentatum, Hald.	Living, Quaternary, Pliocene.

BITUMINOUS FORMATIONS IN FRESNO COUNTY.

There is a seepage of heavy oil in Canours Cañon, in Sec. 28, T. 22 S., R. 16 E., on the Kreyenhagen ranch. The formation yielding the oil is similar to that in Tar Cañon, and is well exposed where the South Fork of the Zapato Chino Creek breaks through the first tier of higher mountains to the west of the foothills. This gap has been worn almost at right angles to the strike of the formation. The first stratum seen on entering the gap is shale, and is very similar in appearance to the shale seen at the entrance to Tar Cañon; it has a strike of 75° west of north. These shales rest on strata of fossiliferous sandstone, from which the following species were obtained:

Ostrea titan, Con.	Miocene.
Ostrea bourgeoisi, Remond	Pliocene.
Pecten discus, Con.	Miocene.
Trophon ponderosus, Gabb	Pliocene, Miocene.
Turritella hoffmanni, Gabb.	Miocene.
Balanus estrellanus, Con.	Miocene.
Astrodapsis antiselli, Con.	Miocene.

Some of the lower fossiliferous strata, like those seen at Tar Cañon, must at one time have contained many shells, but the metamorphic action which they have undergone has nearly obliterated the fossils. The sandstone strata show a dip of from 10° to 20° east of north, the first mentioned direction predominating; the dip is at an angle of about 50°.

As the South Fork of the Zapato Chino Creek is ascended, the sandstone shows increased metamorphism. About one half mile westward from the gap previously mentioned, the mountains are timbered with white oak, cottonwood, and cedar.

A short distance north of the gap through which the Zapato Chino Creek enters the lower foothills, the formation is soft, reddish-brown sandstone. The direction of the dip of this sandstone is 20° east of north, and at an angle of from 35° to 40°. Only three fossils were obtained in this sandstone, viz:

Liropecten estrellanus, Con.	Pliocene, Miocene.
Balanus estrellanus, Con.	Miocene.
Solen rosaceus, Carp.	Living. Pliocene, Miocene.

At the junction of the north and south forks of the Zapato Chino Creek, soft bluish Tertiary sandstone is encountered. The direction of the dip of this sandstone is 25° or 30° east of north, and at an angle of about 35°. At this point the following fossils were obtained:

Balanus estrellanus, Gabb	Miocene.
Cardium meekianum, Con.	Pliocene, Miocene.
Scutella gibbsi, Rem.	Pliocene, Miocene.
Arca microdonta, Con.	Pliocene, Miocene.

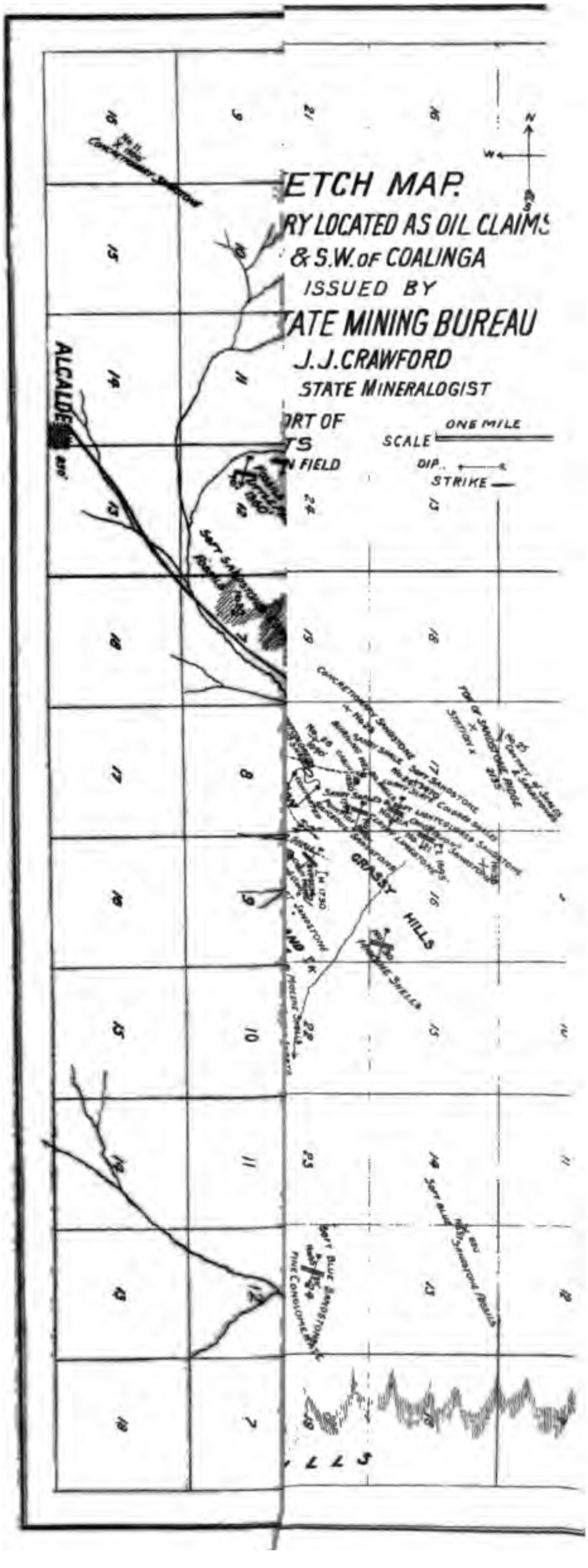
Remarks on the Geology of Tar Cañon and Kreyenhagen Ranch.—The preponderance of Miocene fossils in the rocks yielding the heavy oil, both in Tar Cañon and at the Kreyenhagen ranch, warrants the assumption that the bituminous formations exposed in these localities belong to the Miocene group. The preponderance of Pliocene fossils in the blue sandstone which forms the lower foothills, and which overlies the bituminous formations, is probably sufficient to indicate that the blue sandstone belongs to the Pliocene group. The direction in which the blue sandstone strata dip does not appear to differ very much from that of the Miocene rocks on which they rest, but the angle of inclination is much greater in the latter formation. In the places where the observations herein recorded were made the friable nature of the soft sandstone renders it impossible to estimate the direction of the dip very closely by surface inspection. The average of several observations is therefore given.

OIL CLAIMS IN FRESNO COUNTY.

As will be seen by reference to the accompanying sketch-map, there are two groups of oil claims near Coalinga, in Fresno County. One of these groups is situated a little more than 3 miles in a westerly direction from Coalinga, and the other is about 9 miles distant in a northerly direction from the same place.

The oil claims west of Coalinga cover a territory which lies immediately to the south of the San Joaquin and the California Coal Mines. In order rightly to comprehend the situation, it is necessary to refer to these mines. In the slope last sunk in the San Joaquin Coal Mine, a small quantity of oil was struck in a fossiliferous stratum; and in this mine inflammable gas is frequently encountered. Fossils from a calcareous sandstone in one of the upper tunnels of this mine were classified by Dr. Cooper, as follows:

Modiola cylindrica, Gabb	Cretaceous.
Rimella macilenta, White	Cretaceous B.
Tellina ovoides, Gabb	Cretaceous.
Tapes conradiana, Gabb	Cretaceous B.
Tellina ashburneri, Gabb	Cretaceous.


ETCH MAP.
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SOFT SANDSTONE
MIOCENE SHELLS
SOFT BLUE SANDSTONE
FINE CONGLOMERATE
TOP OF SANDSTONE RIDGE

Chione varians, Gabb	Cretaceous.
Cardium breweri, Gabb	Cretaceous B.
Axinæa veatchi, Gabb	Cretaceous A and B.
Turritella uvasana, Gabb	Cretaceous.
Cardium linteum, Gabb	Cretaceous B.
Tellina hoffmanniana, Gabb	Cretaceous.
Ostrea idriaensis, Gabb	Cretaceous B.
Aucella piochii, Gabb	Cretaceous.
Casts of *Galerus excentricus*, Gabb	Cretaceous.

As only about one third of the species in this collection belong to the "B" series of Cretaceous species, Dr. Cooper is of the opinion that the Coalinga coal measures occupy a lower position in the Cretaceous system than that to which the coal measures of Mount Diablo belong.

The California Coal Mine is about one mile distant, northwesterly, from the San Joaquin Coal Mine, and the workings of both mines evidently penetrate the same coal measures. From a dark-colored clay which forms the hanging wall near the end of the tunnel in the California Coal Mine, the following fossils were secured:

Gyrodes dowelli, White	Cretaceous B.
Clisocolus dubius, Gabb	Cretaceous.
Mytilus quadratus, Gabb	Cretaceous.
Batissa dubia, White	Cretaceous B.
Ostrea idriaensis, Gabb	Cretaceous.
Galerus excentricus, Gabb	Cretaceous.
Perna excavata, White	Cretaceous.

Some new species were also obtained. Dr. Cooper states that the fossils from the California Coal Mine tend to confirm his opinion with regard to the relative age of the Coalinga and Mount Diablo coal measures.

From these fossils Dr. Cooper refers the coal measures penetrated by the San Joaquin and California Coal Mines to the Chico Tejon group of the Cretaceous system. In several places between the two coal mines the formations overlying the coal measures are exposed. The most characteristic rocks that can be seen between the two mines are a peculiar whitish, fine-grained, soft sandstone, and a decomposed, fossiliferous limestone. This limestone is exposed at Station 17 (see sketch-map), but the writer was able to obtain only two fossils which were sufficiently perfect for identification. These were classified by Dr. Cooper as probably of Pliocene age:

Galerus diegoanus, Con.	Living, Pliocene, Miocene.
Modiola capax, Gould	Living, Pliocene.

In the San Joaquin Coal Mine the direction of the dip of the formation is 65° east of north, and the angle of inclination is between 30° and 45°. In the California Coal Mine the direction of the dip is about the same.

Immediately to the westward of the San Joaquin Coal Mine, the formations which appear to underlie the coal measures are exposed, and consist of sandy shale and soft sandstone. The direction of their dip is 55° to 60° east of north, and the angle of inclination appears to be about 50°. These sandy strata appear to rest conformably on hard, gray sandstone, which becomes dark-colored, on the outside, by exposure.

The most characteristic features of this hard, gray sandstone are, that it splits into slabs on weathering, and the plane of cleavage appears to coincide with the lines of sedimentation which mark the original plane of bedding.

This gray sandstone is well exposed at Station 9, and can be traced thence for more than a mile both to the northward and to the southward in the direction of its strike. It is apparently unfossiliferous, and seems to rest conformably on a sandstone of lighter color, which is remarkable for the numerous concretions which it contains. These concretions, which stud the weathered faces of the inclosing rock, are for the most part round in form, and are harder than their sandstone matrix. There is a good exposure of this sandstone at the point marked "Stratified Peak," where these eccentric concretions look like bowlders embedded in the sandstone. A short distance south of Stratified Peak, a stratum of coarse conglomerate extends from Station 6*a* to Station 6. The pebbles forming this conglomerate are quartzose or metamorphic, and are cemented with calcareous material. The ridge of hills on which the conglomerate crops out can be traced as far south as Flag B. Southward from Station 6 the conglomerate disappears beneath the alluvium, but outcroppings of grayish concretionary sandstone can be followed between Station 6 and Flag B. At Station 10, similar sandstone shows a course of 50° west of north. A short distance north of Flag A, a white sandstone, similar in appearance to that seen between the California and San Joaquin Coal Mines, is exposed. This sandstone has a striking resemblance to that found south of the cabin near the gypsum mine, in T. 19 S., R. 15 E. (see sketch-map); also at Station 27 north of Salt Marsh, near the Sunset Oil Wells, in Kern County. South of Flag A, the soft sandstones and sandy shales extend much farther to the westward; and it is this portion of the foothills (*i. e.*, the portion lying southeast of Flag A and north of the railroad between Coalinga and Alcalde) which has been taken up as oil-bearing territory. At Station 1 there is a soft, iron-stained sandstone, traversed by seams of gypsum, and overlaid by a stratum of clayey limestone, from which were obtained the following fossils:

Galerus filosus, Gabb	Pliocene, Miocene.
Saxidomus gibbosus, Gabb	Pliocene.
Tapes staleyi, Gabb	Pliocene.

South of Station 1 the formation is soft sandstone, dipping apparently about 70° east of north. If the dip of this formation is 70° or thereabouts, it does not conform to what seems to be the dip of the stratum from which the fossils were obtained at Station 1. It is impossible, however, to determine exactly the dip of these formations from surface observation, on account of their incoherent nature and the broken character of the outcropping rocks.

At Station 2 a fossiliferous stratum is exposed; but the specimens obtained therefrom were not sufficiently perfect for identification.

At Station 3 there is a spring of tar-like oil, which is accompanied by a small quantity of brine. Farther down the cañon in which Station 3 is situated, there are several brine and sulphur springs; and the formation changes to sandy and earthy shales, which are interstratified with soft sandstone and impure limestone. At Station 4 the direction of the dip of these shales is 80° east of north, and the angle of inclination is about 40°.

In the cañon farther to the northwest (see sketch-map) similar earthy and sandy shales are exposed. In this cañon observations were made at two places, and the direction of the dip of the formation was found to be 65° east of north, and the angle of inclination about 50°. These shales are interstratified with thin strata of concretionary sandstone, impure limestone, and coarse conglomerate; and in one place a stratum containing numerous small fragments of shells was observed. The country in this direction consists of grazing lands, and the superficial deposit of alluvium is very deep. At Station 11, massive strata of concretionary sandstone are exposed.

In traveling eastward to the station marked Little Peak, it was found that the soft shales and sandstones gave place to a fine conglomerate. The direction of the dip of this conglomerate is 70° east of south. The writer is informed that there are seepages of oil and outcroppings of coal in the cañon which extends from the station marked Little Peak toward the cabin.

At Little Peak a fossiliferous stratum of sandy limestone dips 70° east of south, from which the following fossils were obtained:

Arca microdonta, Con.	Pliocene, Miocene.
Axinæa patula, Con.	Miocene.
Cardium quadragenarium, Con.	Living, Quaternary, Pliocene.
Dosinia conradi, Gabb	Pliocene.
Galerus diegoanus, Con.	Living, Pliocene, Miocene.
Galerus filosus, Gabb	Pliocene, Miocene.
Lutricola alta, Con.	Living, Pliocene, Miocene.
Macoma inquinata, Desh.	Living, Pliocene.
Neptunea recurva, Gabb	Miocene.
Pholadidea penita, Con.	Living, Pliocene.
Saxidomus gibbosus, Gabb	Pliocene.
Solen rosaceus, Carp.	Living, Pliocene, Miocene.
Standella falcata, Gould	Living, Pliocene.
Tapes staleyi, Gabb	Pliocene.

At Station 20, in the railroad cutting, strata of sandstone and conglomerate are exposed, from which specimens of *Mytilus mathewsoni* were obtained. At Station 13, in the first tier of foothills bordering the valley lands, there are outcroppings of pulverulent gypsum. In this ridge the following fossils were obtained:

Mya arenaria, Linn.	Living, Pliocene.
Mytilus mathewsoni, Gabb	Miocene.
Pecten nevadanus, Con.	Miocene.
Pseudocardium gabbi, Rem.	Pliocene, Miocene.
Scutella gibbsi, Rem.	Pliocene, Miocene.

Remarks on the Geology of the Hills in which the Coal Mines and the Oil Claims West of Coalinga are Situated.—From the foregoing it is apparent that two geological systems are represented in the territory described. To the first are strata belonging to the Cretaceous system, to which the coal measures penetrated by the San Joaquin and the California Coal Mines belong. It is probable that the sandy and earthy shales which are exposed at Station 4, and in the cañon westward therefrom, are of the same geologic age. To the second belong the Tertiary strata, which constitute the foothills immediately bordering the valley lands, and which are also found resting on Cretaceous rocks. A review of the collection of fossils made in this locality shows that they may be classified according to the vertical range of their species, as follows:

Miocene	3	10 species ranging backward to the Miocene.
Pliocene, Miocene	4	
Living, Quaternary, Pliocene	2	
Living, Quaternary, Pliocene, Miocene	1	
Pliocene	2	7 Pliocene.
Living, Pliocene	5	

The preponderance of Miocene forms indicates that the Tertiary formations of the district under consideration belong to that group.

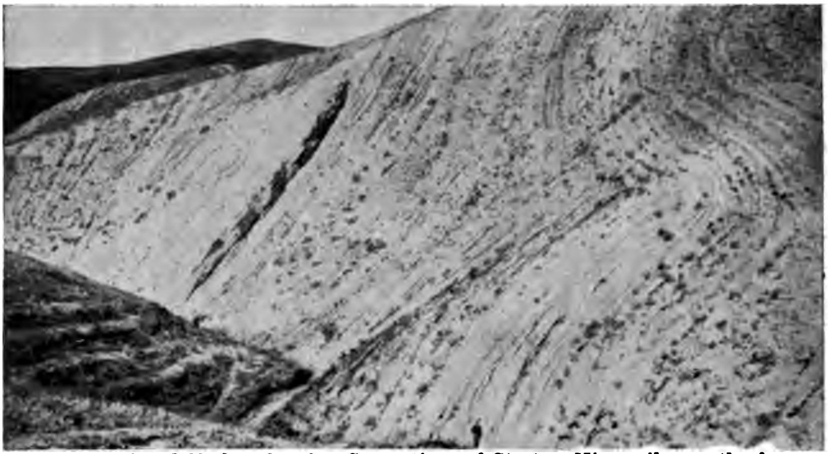
OIL CLAIMS NINE MILES NORTH OF COALINGA.

This oil territory is subdivided by oil claims throughout an area of about 12 square miles. To the westward of this area a ridge of reddish-brown, compact sandstone (Station X; see sketch-map) runs nearly north and south, and is separated from the main Coast Range by a valley which is a few hundred feet in depth. The surface of this ridge is covered with protruding weatherworn crags of sandstone, many of which split into slabs, and the plane in which the sandstone cleaves is apparently coincident with the lines of sedimentation which mark the plane of its original bedding. The summit of this ridge has an altitude of about 2,300 feet. Although this ridge was carefully inspected, no strata were found sufficiently well defined to enable one to estimate the dip and strike of the formation. The sandstone composing this ridge contains rounded concretions, and resembles that found to the westward of the San Joaquin and the California Coal Mines, which is probably Cretaceous.

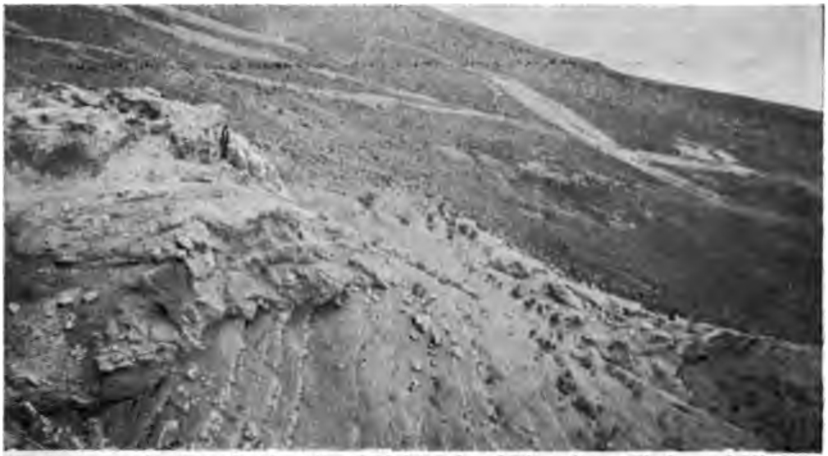
Between this ridge and the San Joaquin Valley are tier after tier of foothills. Their surface is covered with alluvium, and deeply furrowed with gulches and ravines, and here and there patches of the underlying rocks are exposed. First in order are seen drab and slate-colored patches and slopes, marking the formation in which the oil wells are bored. This formation consists, for the most part, of sandy or earthy shales and soft sandstones.

The oil obtained from these wells is of a remarkably low specific gravity. (See table of oil analyses.) Farther eastward are whitish hills, which are composed of light-colored shale yielding a heavy, tar-like oil. These light-colored shales appear to have been subject to considerable geological disturbance, and wavy lines, caused by the curious contortions of their strata, are noticeable through the scanty herbage with which the hills are covered. Still farther in the eastern distance are seen drab-colored and whitish escarpments, which expose Tertiary strata dipping in an easterly direction toward the San Joaquin Valley. This latter formation, in the lower strata of which the gypsum mine hereinafter described is situated, appears to rest unconformably on the light-colored shales. (See illustration.) The last tier of hills seen to the eastward consists of grassy slopes; and these subside into the mesa lands which form the western boundary of the San Joaquin Valley. The most easterly outlying foothills are principally formed of soft bluish sandstone, similar to that found at the Kettleman Hills and the Krayenhagen ranch. Turning to the westward the eye falls on the more lofty elevations of the Coast Range, which culminate at the point marked "Apparent apex of main range" in the sketch-map.

Descending from the sandstone ridge to the head of a cañon leading to the oil wells, a point is reached where a tunnel has been run into the



Light-Colored Shales, showing Contortions of Strata. Nine miles north of Coalinga, Fresno County.



Contact, showing Non-Conformity of Light-Colored Bituminous Shales and Miocene Strata which rest upon them. Nine miles north of Coalinga, Fresno County.

Gypsum Mine, nine miles north of Coalinga, Fresno County.

sandstone for water. At the time of the writer's visit this tunnel could not be explored, as the water it yielded had been dammed up in the tunnel, forming a reservoir to supply sheep-troughs erected near by. The water is very hard. At Station 25 the slate-colored shales can be seen in contact with the sandstone, but the exposure is a poor one.

In the cañon which leads in a southeasterly direction from the sheep-troughs, the formation is dark-colored shale and soft sandstone. These rocks are interstratified with a few thin courses of impure limestone; and in some places the shale exhibits a variety of strike and dip within a small area. At one point, however, a sandy shale, which appears to be in place, shows a dip of 50° east of south, and an angle of inclination of about 35°. It is probable that these figures approximately represent the prevailing dip of the dark-colored shales. Farther to the northward, slopes of slate-colored shale are exposed, in which there are several springs of sulphuretted water. This bluish shale extends to the ridge of hard, concretionary sandstone previously mentioned. Shortly before reaching the hard sandstone ridge, this shale is traversed by a few strata of soft sandstone; it is so at Station 24, and in one place a thin stratum of magnesian limestone crops out. It is in these dark-colored shales that the oil wells have been bored. The wells marked "oil wells" in the accompanying sketch-map are situated in a depression in the hills. There are five of these wells, namely:

One 4-inch well, in which an oil of low specific gravity stands within 32 feet of the surface, and inflammable gas bubbles freely through the oil. (See table of oil analyses.)

One 4-inch well, plugged.

One 7-inch well, plugged.

One 14-inch well, from which oil and water flow, and inflammable gas rises. In November, 1893, this well was burning fiercely, and a small stream of mineral water and a little oil flowed from the top of the casing. (See table of water analyses.)

One 10-inch well, plugged.

The formations immediately overlying the strata pierced by the oil wells are exposed along the road leading to Coalinga, which runs through a cañon to the eastward of the oil wells. First, a dark-colored shale is seen, the laminæ of which are separated by an ocherous material. Overlying this shale are thin strata of fissile sandstones and impure limestones; and overlying these are light-colored bituminous shales, resembling the light-colored bituminous shales seen at Asphalto, and at the Sunset Oil District, in Kern County. The light-colored shales of Coalinga, like those of Kern County, are very silicious, and vary in color from drab to almost white. Two specimens were examined, which, in round figures, showed as follows:

	Percentage of Specimens Insoluble in Acid.	Percentage of Silica Contained in Specimen, which was Soluble in Sodium Carbonate.	Total Amount of Silica Contained in Specimen.
(*a*)	90	Not determined.	80
(*b*)	91	27	86

Sample *a* was a drab-colored shale; it also contained 7.5 per cent of iron and aluminum (weighed together as sesqui-oxides). The specimen showed quantitatively calcium and magnesium.

Sample *b* was a soft, white shale containing marine diatoms. It showed qualitatively similar constituents to sample *a*, but alumina was only present in traces.

In this formation the scales of fish and a few bones of small fish were found; also several casts of *Pecten peckhami* (Gabb), Mioc.

As shown in the sketch-map, there is a spring of heavy oil in this cañon (see table of oil analyses); and immediately above the spring a bituminous sandstone is exposed. The prevailing direction of the dip of the formations cut through by this cañon appears to be approximately 15° east of south.

Returning to the oil wells the writer explored the little cañons leading up the side of the hills which rise immediately to the southeast of the oil wells. The formation exposed in these cañons is principally earthy and sandy shales containing crystallized gypsum. At Station 22 a stratum of clayey limestone shows a dip of 70° east of south, and the angle of inclination is about 35°. From this clayey limestone the following fossils were obtained:

Discohelix leana, Gabb	Cretaceous A.
Turritella saffordi, Gabb	Cretaceous A.

At Stations 21 and 21*a*, a stratum of calcareous sandstone is exposed, which dips in the same direction as the clayey limestone noted at Station 22. From this calcareous sandstone several fossils were secured, which were determined by Dr. Cooper to be:

Axinæa sagittata, Gabb	Cretaceous B.
Ficopsis cooperi, Gabb	Cretaceous B.
Turritella uvasana, Gabb	Cretaceous A.
Tritonium californicum, Gabb	Cretaceous B.

Farther eastward the formation changes to the light-colored, porous, silicious shales previously described. These shales may be seen cropping out near the summits of some of the hills. The best opportunity for examining them, however, is in a little cañon which leads off in a northeasterly direction from the cañon traversed by the road running between the oil wells and Coalinga. In this subsidiary cañon the light-colored shales are well exposed; a heavy, tar-like oil and sulphuretted water ooze from the shale in several places, and a small amount of asphaltum has been formed. This light-colored shale is much contorted and shows a huge fold, which extends across the little cañon. (See illustration.) At this point the dip of the shale varies from 15° east of south to 25° west of south. In the northern extremity of this cañon the strike of the shale is 50° east of south, and the dip northerly.

On the summit of the adjacent hills the shale is bent and flattened. About 1¼ miles southeast of the burning well another cañon extends in a northeasterly and southwesterly direction. It is in this cañon that the gypsum mine, hereinafter described, is situated. Shortly before reaching the cabin belonging to the owners of the gypsum mine, the light-colored shale is cut through by a road leading to the mine. At Station 33 there is a spring of sulphuretted water and tar-like oil. The shale shows a dip of 85° west of north, and an angle of inclination of about 40°. Following up the bed of this cañon the light-colored shales show evidence of great disturbance; the direction of its dip varies from 15° to 70° east of south, and the angle of inclination varies from 35° to more than 80°. Near the upper end of the cañon the dip of the shale is 10° east of north, at an angle of 70°, and a little farther northward it is 5° west of north, at an angle of 80°. At the upper extremity of the cañon the dip is 35° east of north, and the angle of inclination is 60°. Toward the upper end of this cañon there are two or three seepages of sulphuretted water, and the shale is indurated with silica. These shales are overlaid by strata of soft sandstone and conglomerate, which have a dip of 50° east of south, at an angle of apparently not more than 25°. (See illustration.) Immediately to the eastward of the cabin belonging to the Gypsum Company are bluffs of soft friable sandstone. The upper portion of this sandstone is light-colored, but the lower portion is black, weathering to gray on the outside. This sandstone resembles sandstone seen near the asphaltum mines in Kern County. It is in the formation immediately overlying the contorted shales, and about 50 feet above the bottom of the above-mentioned cañon, that the gypsum mine, which at the date of visit was being worked, is situated.

THE COALINGA GYPSUM MINE.

This mine was opened in November, 1892, and is owned by Hall, Doverall & Lavelle, of Visalia, who erected a mill at Coalinga for grinding the rock. The workings at this mine consist of two open cuts. At one of these cuts, which has been made for a distance of about 60 feet in the hillside, the stratum which is being mined is about 10 feet in thickness. The foot wall is soft sandstone, and the hanging wall, light-colored shale. The formation dips from 45° to 50° east of south at an angle of not more than 20°, perhaps not so much. At the other open cut, which is probably 100 yards south of and 25 feet below the cut already described, there are two distinct strata from which the gypseous material is obtained. These strata are separated by light-colored, sandy shale and clayey and calcareous matter. The writer is informed that about 500 tons of material have been taken from these mines, and that it finds ready sale as land-plaster in Tulare and Fresno Counties. The summit of the hill in which the gypsum mine is situated is marked Flag H in the accompanying sketch-map. Near the top of the hill there are outcroppings of rock very similar in appearance to that which is being taken out of the gypsum mine.

A short distance below this summit, the hillside is traversed by fossiliferous strata, principally calcareous sandstone. Fossils obtained from these strata proved principally to consist of Miocene species, as follows:

Axinæa patula, Con.	Pliocene, Miocene.
Dosinia conradi, Gabb	Miocene.
Mytilus mathewsoni, Gabb	Miocene.
Ostrea titan, Con.	Miocene.
Ostrea bourgeoisi, Remond	Pliocene.
Pecten nevadanus, Con.	Pliocene, Miocene.
Balanus estrellanus, Con.	Miocene.
Scutella gibbsi, Rem.	Pliocene, Miocene.

It is said that gypsum was also formerly mined at the point marked Station 27; but the writer is informed that so much material which was not gypsum was shipped, that the work had to be abandoned. An old sled road marks the scene of former mining. There are several openings not very far away, around which a white rock, which may contain gypsum, is piled up. The formations which rest unconformably on the light-colored shales in this locality, are composed of soft sandstones and calcareous and gypseous strata, some of which are fossiliferous, as previously noted. Conspicuous amongst the sandstones is a peculiar, white sandstone similar to that observed near Station 1, in the oil district southwest of Coalinga, and at Salt Marsh, in Kern County.

About half a mile in a northeasterly direction from the gypsum mines a deep cañon leads in an easterly direction, and at one point therein contorted silicious shales are exposed. In this cañon there is also a spring of mineral water, from which sheep-troughs are supplied. This cañon cuts through a ridge of sandstone and calcareous strata, which dip in an easterly direction, and appear to rest somewhat unconformably on the formation in which the gypsum mine is situated; but the strike and dip of these soft, sandy rocks are very difficult to determine with accuracy, especially when they are much eroded. The strata forming the ridge are very regular, and lie conformably on one another with no signs of folding or contortion. The formation comprising this ridge was examined at points marked Flag K and Stations 30 and 32. From the calcareous sandy strata at the points named the following fossils were obtained:

Ostrea titan, Con.	Miocene.
Liropecten crassicardo, Con.	Miocene.
Liropecten estrellanus, Con.	Miocene.
Balanus estrellanus, Con.	Miocene.
Tamiosoma gregaria, Con.	Miocene.
Pecten discus, Con.	Pliocene, Miocene.

In some places these shell-beds are composed almost entirely of the species named. It is said that these fossiliferous formations can be traced for a distance of more than two miles. The writer was informed that there is a seepage of oil in a cañon to the northeast of Flag K, but he could not find it.

At Station 31 an escarpment of soft sandstone is exposed, forming a cliff of about 200 feet in height. This sand is brownish, and is interstratified with black sand, and contains seams of gypsum; some of the strata of black sand are quite thick. The only organic remains which could be found in this formation are logs of silicified wood. Some portions of the cliff show numerous concretions in the process of formation. A spherical shell of gypsum or oxide of iron forms around a mass of sand, the inclosed mass appearing to grow harder and harder by the action of infiltering water, until a nodule is formed. This formation rests on strata of light-colored, sandy clays and strata of fine conglomerate; it dips 60° east of south, at an angle of about 20°.

After crossing about 1½ miles of grazing land in an easterly direction, a low range of hills is reached at Station 34. The formation is soft, grayish-blue sandstone; the dip appears to be 80° east of north, and at an angle of about 20°. At this station the following fossils were obtained:

Cardium corbis, Martyn	Living, Pliocene.
Cardium meekianum, Gabb	Pliocene, Miocene.
Columbella richthofeni, Gabb	Pliocene.
Macoma edulis, Nut.	Living, Pliocene, Miocene.
Margarita pupilla, Gould	Living, Quaternary.
Mytilus mathewsoni, Gabb	Miocene.
Nassa californica, Con.	Living, Pliocene, Miocene.
Pecten islandicus, Müll.	Living, Pliocene.

Saxidomus gibbosus, Gould	Pliocene.
Schizothœrus nuttali, Con.	Living, Pliocene.
Balanus estrellanus, Con.	Miocene.

At Station 37 soft blue sandstone is again exposed, but the only fossils found at this point were:

Galerus diegoanus, Con.	Living, Pliocene, Miocene.
Modiola capax, Gould	Living, Pliocene.
Scutella gibbsi, Rem.	Pliocene, Miocene.
Balanus estrellanus, Con.	Miocene.

The soft bluish sandstone is again seen at Station 35, where it is interstratified with fine pebbles. The dip of the formation appears to be very slightly north of east, and at a very low angle. The last tier of foothills is reached at Station 16, at an altitude of about 825 feet.

Remarks on the Geological Formations of the Oil District Nine Miles North of Coalinga.—From the foregoing it is obvious that the formations exposed in this oil district represent several epochs in the geological history of the Coast Range, and may be enumerated in what appears to be the order of their superposition, as follows:

Cretaceous:

1. Concretionary sandstone, unfossiliferous.
2. Slate-colored shales passing into earthy or sandy shales, with strata of soft sandstone. This formation contains oil of low specific gravity, and in the uppermost strata of it late Cretaceous shells are found.

Miocene:

3. Light-colored porous silicious shales, which yield heavy, tar-like oil and asphaltum. The only fossils found in these shales were *Pecten peckhami* (a Miocene fossil), a few fish bones, and marine diatoms.
4. Soft sandstones and calcareous and gypseous strata, containing Miocene fossils. These rocks appear to rest unconformably on the light-colored silicious shales, but their slight angle of inclination raises a suspicion that they may belong to a series of strata which are higher in the order of upward vertical range than their position with regard to the light-colored shales might lead one to suppose.
5. Sandy formations containing immense numbers of *Ostrea titan*, *Liropecten*, and *Tamiosoma.*
6. Soft brown and black sands, containing numerous logs of petrified wood.

Pliocene:

7. Soft bluish-gray sandstone and fine conglomerate, containing Tertiary fossils. The fossils collected in these sandstones show a preponderance of species which have a vertical range extending upward from the Miocene group. Some idea as to the thickness of the Tertiary formations overlying the light-colored shales may be gathered from the accompanying sectional sketch, which represents a cross-section from Station 36, in the foothills, to the concretionary sandstone beneath the dark-colored shales in which the oil wells are bored.

Records of Wells which have been Bored in the Oil District Nine Miles North of Coalinga.—Opinions differ as to the results which have been attained by boring in this district, and various reasons are given for the wells being plugged or abandoned. The following is all the data concerning these wells which it has been possible to gather:

The first well of which any record is extant, was sunk several years ago by the Coast Range Oil Company, of Los Angeles. This well is one of the group marked on the sketch-map. The formation penetrated is as follows:

Dark-colored shale, containing a small amount of green oil and inflammable gas	65 feet.
Soft, light-colored sandstone, and a thin stratum of limestone; altogether	50 feet.
At this depth there was a great increase in the amount of gas.	
Dark-colored shale	163 feet.
This shale contained a little green oil and much gas.	

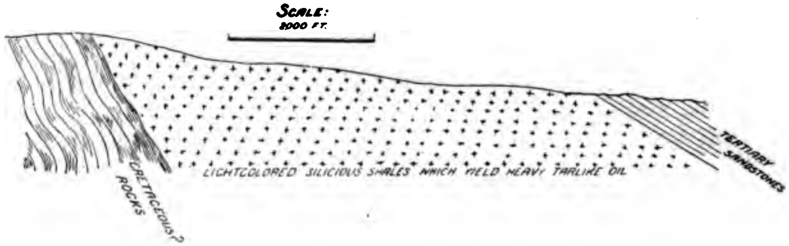
Beneath the shale a dark-colored sandstone was struck, from which a greenish oil of light specific gravity rose to the surface and flowed slightly. A windmill pump was attached to this well, and 10 barrels of oil were pumped from it daily for two days. The third day, the well yielded 7 barrels of oil.

Another gentleman, who bored one of the 4-inch wells, has been kind enough to supply the following record:

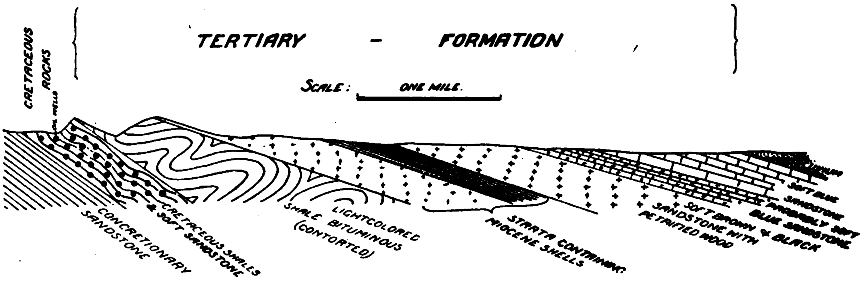
Alluvial soil	30 feet.
Black shale	100 feet.
Soft sandrock	20 feet.
Black shale	45 feet.
Sandstone	15 feet.
Shale	50 feet.
Oil sand	10 feet.
Black shale	105 feet.
Total depth of well	400 feet.

This well was tested by pumping, and was found to yield from 8 to 10 barrels daily. The gentleman who tested the 4-inch well states that the 10-inch well previously mentioned is about 650 feet in depth, and that he thinks it yielded about 40 barrels of oil a day. He also says that one of the other wells is 500 feet deep, but that it was never pumped.

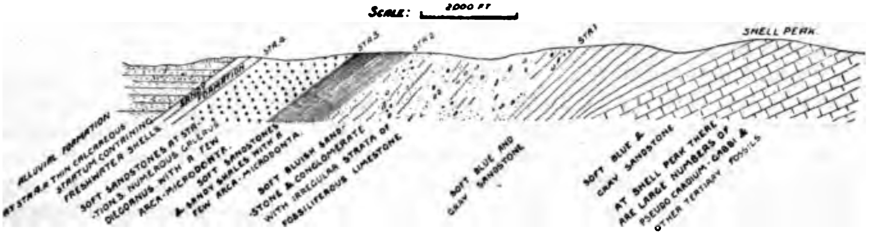
SECTION SHOWING APPROXIMATELY THE MAXIMUM THICKNESS OF LIGHTCOLORED SHALES EXPOSED IN THE SUNSET OIL DISTRICT. KERN COUNTY.



SECTION ACROSS OIL DISTRICT N. OF COALINGA.


TERTIARY - FORMATION
SCALE: ONE MILE.
CRETACEOUS ROCKS
OIL WELLS
CONCRETIONARY SANDSTONE
CRETACEOUS SHALES & SOFT SANDSTONE
SHALE BITUMINOUS (CONTORTED)
LIGHTCOLORED
STRATA CONTAINING MIOCENE SHELLS
SOFT BROWN SANDSTONE WITH PETRIFIED WOOD
PROBABLY SOFT BLUE SANDSTONE & BLACK
SOFT BLUE SANDSTONE
ALLUVIUM

SECTION of TERTIARY STRATA in KETTLEMAN HILLS.


SCALE: 2000 FT
STRA 4
STRA 3
STRA 2
STRA 1
SHELL PEAK
SANDY FORMATION
ALLUVIAL FORMATION
STRATA & THIN CALCAREOUS STARTUM CONTAINING FRESHWATER SHELLS
SOFT SANDSTONES AT STRA-TIONS NUMEROUS GALERUS OILGORNUS WITH A FEW ARCA-MICRODONTA.
SOFT SANDSTONES & SANDY SHALES WITH A FEW ARCA-MICRODONTA.
SOFT BLUISH SAND-STONE & CONGLOMERATE WITH IRREGULAR STRATA OF FOSSILIFEROUS LIMESTONE
SOFT BLUE AND GRAY SANDSTONE
SOFT BLUE & GRAY SANDSTONE
AT SHELL PEAK THERE ARE LARGE NUMBERS OF PSEUDO CARDIUM-GABBI & OTHER TERTIARY FOSSILS

REMARKS ON THE OIL-YIELDING AND GAS-YIELDING FORMATIONS IN THE CENTRAL VALLEY OF CALIFORNIA.

We have now traced the occurrence of oil and gas in both the Sacramento and the San Joaquin Valleys, and can see how the geological conditions under which the gas is found in the Sacramento Valley compare with the geological conditions under which it is found in the valley of the San Joaquin. In the foothills of the Sacramento Valley, gas and oil are found in Cretaceous formations, and gas is noted issuing from deep wells which penetrate the Quaternary filling of the valley. In the foothills of the San Joaquin Valley, gas and oil are found in formations of both Cretaceous and Tertiary age; and inflammable gas is observed issuing in quantities of commercial value from deep wells penetrating the Quaternary filling of the valley. We have seen that wells penetrating the Upper Cretaceous strata north of Coalinga yielded inflammable gas and an oil of a peculiarly low specific gravity. The Cretaceous formation no doubt underlies the whole of the Central Valley of California. As previously stated, rocks of this age can be traced on both sides of the Sacramento Valley. In the San Joaquin Valley, Cretaceous rocks have been observed as far south as the Tejon Pass. The writer has found fossils of this age in San Emidio Cañon, in the foothills near Coalinga, and near Merced Falls in Merced County. At the latter place (see our XIth Report p. 257), there is a range of low hills of sandstone, from which specimens of *Cardita planicosta* were obtained, showing the formation to belong to the Cretaceous B (Chico Tejon) series.

The principal showing of Tertiary hydrocarbons on the western side of the San Joaquin Valley is found in what appears to be the lowest formation belonging to the Tertiary system. As previously noted, these lower Tertiary strata consist of a peculiar, porous, silicious shale, which yields a heavy, tar-like oil. Heavy oils are also found in some of the sandy strata, which appear to be of more recent origin than the light-colored shales. Thus, seepages of tar-like oil exude from Tertiary sandstone at the Krayenhagen ranch, at Tar Cañon, and at Asphalto; and bituminous sands, which are probably of this age, are found on the banks of Kern River on the eastern side of the San Joaquin Valley. There are also many other places in the foothills on the western side of the San Joaquin Valley where bituminous Tertiary sandstones are exposed.

The bituminous shales exposed in the Sunset Oil District show a maximum thickness which may be approximately estimated at 2,700 feet, but exposures of this formation seen north of Coalinga and near the Vallecitos Creek, in San Benito County, convey the idea that it becomes

Gas-Yielding Strata in the Jackson Well No. 2.

Character of Strata.	Thickness of Strata, in Feet.	Depth of Well, in Feet.
Soft sand-rock	34	746 to 800
Coarse sand, with good flow of water and gas	10	870 to 880
Porous cement, with good flow of water and gas	16	880 to 896
Porous, sandy cement, with gas	30	1,000 to 1,030
Sand, with water and gas	10	1,170 to 1,180
Sand, with water and gas	10	1,260 to 1,270
Sand, with large flow of water and gas	15	1,445 to 1,460
Porous, sandy stratum, yielding much gas	10	1,630 to 1,640
Sand, with large flow of water and gas	5	1,650 to 1,655
Total thickness of gas-yielding formations	140	

It appears from the records of Jackson Well No. 2, the Court-house well, and the Northern well, that the average thickness of gas-yielding strata for wells 1,600 to 1,700 feet deep may be put down approximately at 150 feet. Below that depth, the proportion of gas-yielding strata greatly increases, and it is the opinion of those who have bored deeper wells at Stockton, that below a depth of 1,700 feet all the porous strata yield gas.

Concerning the tension of the gas in the gas-yielding strata, the problem is complicated by the presence of flowing water which has been struck in nearly all the gas-wells hitherto bored in the valley lands. The flowing water is, however, a qualified misfortune, for not only is it in itself of great service to the community, but it is a safeguard against waste, such as was occasioned in the Eastern States by an unimpeded flow of gas. If the water could be kept out of the casing without obstructing the flow of gas, there is no doubt but that the amount of gas yielded by the wells would be greatly increased. The only information that could be obtained on this important subject is as follows:

In the Jackson Well No. 2 some gas was obtained before flowing water was struck. In the St. Agnes Well No. 1, only about a mile distant from the Jackson wells, when the water ceased to flow the well ceased to yield gas. In the Haas well, which is probably a mile and a half from the Jackson well, the force of the gas, when the well was virtually capped by the boring tools, drove the water out of the hollow boring-rod, and burst the fire hose attached to it. Mr. Haas is of the opinion that the pressure equaled 200 pounds to the square inch. In this connection we call to mind the fact that the gas which blew the water out of the casing of the Jacobs well in Tulare County must have been under a pressure of more than 105 pounds to the square inch.

It is impossible to determine to what extent the Tertiary rocks may have been eroded in central portions of the valley, but it is quite likely that Tertiary strata several thousand feet in thickness underlie the Quaternary filling of the valley. If such strata should contain gas, its tension would be much greater than in strata near the surface, and the amount of water might be much less.

A great increase in the depth of wells is limited by questions of cost and practicability; but all circumstances connected with the question of "natural gas" in the San Joaquin point to the fact that deep wells produce the best results.

There is one point on which the reader will probably wish to know something, and that is the cost of well-boring in the Central Valley of California. Concerning the cost of well-boring, the writer has not yet sufficient data to give very satisfactory information, but he is informed that the Court-house well at Stockton, which is said to yield 30,000 cubic feet of gas daily, cost about $12,000, including the cost of gasometer and the necessary plant.

THE LEADING GEOLOGICAL FEATURES OF THE OIL-BEARING FORMATIONS OF THE SAN JOAQUIN VALLEY.

The most characteristic rock of the bituminous formations of the Coast Range is the light-colored, silicious, bituminous shale. These shales are described by Professor J. D. Whitney in Geology of California, vol. 1, and more recently in a bulletin published by the University of California, entitled "The Geology of Carmelo Bay," by Dr. A. C. Lawson, assisted in chemical analysis and field-work by Juan de la Posada. It is impossible to read the descriptions of this shale in the works referred to, and then to examine the light-colored shale mentioned in the foregoing pages, without at once recognizing the probability of the formations being identical. Dr. Lawson has described the samples of shale which he found in Monterey County somewhat exhaustively from a lithological point of view; he regards the rock as being indirectly of volcanic origin, and states that it is probably made up of a very silicious volcanic ash. In comparing the samples of light-colored shale obtained near Coalinga with samples from Kern County, the writer spent no more time in laboratory work than was required to bring out the leading features necessary to demonstrate a similarity in the composition of the light-colored shales seen in Kern and Fresno Counties.

The facts here relied on to establish the identity of the light-colored shale formation exposed in both counties, are as follows: Both at the San Emidio Grant, in Kern County, and in the oil district nine miles north of Coalinga, these shales are found beneath strata containing Miocene fossils. The physical appearance of the light-colored shales both in Kern and Fresno Counties is very similar, not only when studied as a formation, but also when hand specimens are subjected to macroscopic examination. After these shales have been treated with acid to remove soluble infiltrations, they are found to be largely composed of silica, and a notable percentage of this silica is soluble in a solution of sodium carbonate. These shales, both in Kern and Fresno Counties, yield a heavy, tar-like oil, and contain marine diatoms. Samples of light-colored shale from the oil district nine miles north of Coalinga, the Sunset Oil District, and Asphalto, were examined by Mr. D. C. Booth, of the San Francisco Microscopical Society, who makes the following statement: "The sample of light-colored shale from the oil district nine miles north of Coalinga contained numerous diatoms, and some specimens contained the spicula of sponge. The species of diatoms most abundant in the specimen furnished me are: *Actinoptychus*, *Raphoneis*, *Actinocyclus*, *Coscinodiscus* (3 var.), *Navicula* (2 var.), and *Hyalodiscus*—all marine species. The specimens of light-colored shale from the Sunset Oil District do not contain many diatoms, but what appears to be the silicious epidermis of algæ is abundant. In some specimens from this locality I found the spicula of sponge and foraminifera. The soft silicious rock from Asphalto contains numerous *Coscinodiscus*, and a few

Raphoneis; and both these diatoms appear to be of the same varieties as the *Coscinodiscus* and *Raphoneis* in the sample of light-colored shale from Coalinga."

The necessity of producing the aforementioned evidence to establish the identity of the light-colored shale exposed in the oil district nine miles north of Coalinga and that seen in the Sunset Oil District, arises from the impossibility of tracing the formation continuously between the two places. This disappearance of the light-colored shales ceases to be surprising when we find sandy Miocene formations resting unconformably on the light-colored shales in the oil district nine miles north of Coalinga. Another interesting geological feature is the contortion which the light-colored shales have undergone in some places. This contortion, as suggested by Dr. Cooper, may be due not only to the folding incidental to orographic movement, but to an irregular subsidence caused by the escape of gas, oil, or other matter once contained by the light-colored shales, or by strata on which they rest. It will, no doubt, be observed by the reader that only scanty exposures of what are believed to be earthy Cretaceous shales were noticed in the Sunset Oil District, and that no mention is made of them at Asphalto, although the light-colored shales are well exposed at both places. This awakens a suspicion that the light-colored shales rest unconformably on the Cretaceous strata. This, however, is not established by the observations herein recorded. The most that can be safely said on the subject is, that at Sunset the light-colored shales appear to be less disturbed than the strata on which they rest, and that in the oil district north of Coalinga the reverse seems to be the case. But formations which are conformable in one locality may be unconformable in another.

An interesting line of inquiry presents itself in the gradual increase in the easterly direction of the dip exhibited by the strata composing some of the formations herein described, when they are examined in the order of their upward vertical range. It is to be hoped that these investigations will be supplemented by the work of others who have both the means and the time for exhaustive scientific research.

ESTIMATION OF FUEL VALUE OF NATURAL GAS AT STOCKTON.

Having dwelt somewhat largely on the geological features attending the occurrence of natural gas, in both the San Joaquin and the Sacramento Valleys, it is now in order to consider the value of the gas as fuel. It has for some time been the endeavor of the State Mining Bureau to obtain reliable information upon this subject from the experience of those who have used the gas. A review of the information collected under this head shows a wide difference of experience and opinion; this, however, is by no means surprising when we consider the lack of uniformity in the conditions under which the gas has been burned. It was concluded that under the circumstances the best results in this investigation could be obtained by physical experiment. The plan chosen was the comparison of work done by burning measured quantities of hydrogen with work done by measured quantities of natural gas burned under practically similar conditions. To this end a cylindrical boiler was made capable of holding 6,700 cubic centimeters of water, the tare of the boiler for purposes of calormetric estimation having an equivalence of 270 cubic centimeters of water. The height of the boiler was 20 inches, and its diameter 6 inches. A funnel-shaped fire-box formed the base of the boiler and connected with an air-chamber, from which a flue for the escape of the products of combustion extended through the upper portion of the boiler and protruded from its top. The air-chamber was so constructed that it would retain any water that might be condensed from the products of combustion. It was found that, although several cubic centimeters of water were condensed during short experiments, only an insignificant amount remained at the close of the experiments herein recorded. The outer portion of the boiler was of tinned iron, and the fire-box, air-chamber, and flue were made of copper. When this instrument was in use it was surrounded by a screen of thick asbestos paper, and the boiler was insulated by asbestos, as much as possible, from the iron ring-stand upon which it stood. Bunsen burners were employed. The test-meter used was manufactured by the American Meter Company. Repeated experiments with hydrogen showed that the best results were obtained with a five-jet burner, in which the air passages at the base of the jets were about two-thirds closed. The hydrogen was prevented from "snapping back" by the insertion of platinum gauze in the tips of the burners. Under these conditions very uniform results were obtained.

Repeated experiments with the natural gas showed that the best results were secured by using a Bunsen burner in which three jets fed an Argand nozzle, while a single jet, the tip of which formed a center to the base of the nozzle, supplied an independent flame; this flame in its passage upward superheated, to some extent, the gas passing through the Argand nozzle. A series of experiments showed that the most heat was obtained from the natural gas by regulating the flow so that a flame was produced blue at the base, and passing through various shades of dull red to a yellow color at the edges and in the upper portions of the luminous cone. In the experiments with both the hydrogen and natural gas the tips of the burners were on a level with the base of the boiler. By carefully noting the color of the flame, and instantly repressing any tendency to roar or flicker, very uniform results were derived from experiments made with the same bagful of natural gas. At Stockton, the natural gas was conveyed in a rubber bag directly from the wells to a room wherein the experiments were conducted; and as the tabular statement hereto annexed shows, the conditions were as uniform as the circumstances would allow.

Gas was taken from the following wells: St. Agnes, Court-house, Asylum, Northern, Jackson, Citizens, and Haas. In this article these wells are referred to by numbers and not by names, nor are the numbers in the order in which the wells have just been mentioned. The only exception made is in the case of the Asylum well.

As the following table of results shows, only in one instance was any noteworthy difference observed in fuel value of the gas yielded by the various wells:

Table recording the Experiments with Natural Gas and Hydrogen, and showing the Conditions under which they were Conducted.

Wells.	Barometric Pressure Approximated by a Pocket Aneroid.	Amount of Gas Burned	Temperature of Gas	Open Pressure of Gas in Meter	Temperature of Air	Temperature of Water at Beginning of Experiment	Temperature of Water at End of Experiment	Number of Degrees Water was Raised	Number of Degrees for Each Foot of Gas Burned	Duration of Experiment	Average Temperature at which Products of Combustion were Lost
		Cubic Feet.		Inch of Water.						Minutes.	
The Asylum	29.50 in.	3	17.60° C.	.6	13.00° C.	14.00° C.	67.00° C.	53.00° C.	17.66° C.	36.00	37.00° C.
Well No. 1		3	15.40	.6	18.00	16.00	68.75	52.75	17.58	31.00	36.00
Well No. 2		3	13.20	.6	17.00	15.75	64.75	49.00	16.33	42.00	35.00
Well No. 3		3	15.40	.6	15.40	17.00	70.75	53.75	17.91	48.00	35.60
Well No. 4		3	16.50	.6	16.50	16.00	70.25	54.25	18.08	46.00	36.40
Well No. 5		3	17.60	.6	17.60	17.00	70.25	53.25	17.75	40.00	35.60
Well No. 6		3	17.60	.6	17.60	16.50	70.00	53.50	17.83	46.00	37.10
		3	113.30	.6	115.10	112.25	481.75	369.50	123.14	289.00	252.70
Average for natural gas		3	16.18	.6	16.44	16.03	68.82	52.78	17.59	41.30	36.10
Experiment with hydrogen	29.65 in.	7	15.00	.6	15.00	16.20	72.20	56.00	8.00	44.00	34.00

Another sample taken from the Asylum Well and from Well No. 2 showed as follows:

Asylum.										
Second sample taken 3 days after first sample	3	13.75° C.	.6	14.90° C.	16.00° C.	68.00° C.	52.00° C.	17.50° C.	32.00	39.00° C.
No. 2.										
Second sample taken 2 days after first sample	3	13.20	.6	13.75	15.00	63.50	48.50	16.25	41.00	38.00

If the temperature of the gases had been reduced to 0° C., disregarding fractional differences resulting from a slightly increased loss by radiation and conduction, the work performed by the three feet of natural gas and the seven feet of hydrogen, respectively, would have been practically as follows:

Average sample of natural gas	3	0.00° C.	.6	16.44° C.	16.00° C.	72.90° C.	56.90 ~~55.90~~° C.	18.96 ~~18.63~~° C.	43.74	38.23° C.
Experiment with hydrogen	7	0.00	.6	15.00	16.20	76.16	59.07	8.44	46.40	35.86

As hereinafter described, the loss of heat by radiation and conduction under the conditions attending the experiment with hydrogen was approximated experimentally and found to be 2.17° C.

In the foregoing experiments the temperatures at which the products of combustion were lost increased as additional gas was consumed and the temperature of the water in the boiler rose. In the subsequent estimates as to the value of the gases at 0° C., a rise in the temperature at which the products of combustion would have been lost is therefore calculated corresponding to the increased calorific value of the gases at 0° C. Moreover, as the density of the gases would be increased by reduction to zero, the time representing the duration of the experiment is also proportionately lengthened.

The experiments are thus placed on as equal a footing as the conditions will permit. It was found that the work done by 1 foot of hydrogen, its temperature being 0° C., was to raise the temperature of the water in the boiler 8.44° C., while an average foot of natural gas at a temperature of 0° C. raised the water in the boiler 18.63° C.

By comparing the work done it was found that 1 foot of natural gas performed as much work as 2.207 cubic feet of hydrogen. Taking the weight of 1 cubic foot of hydrogen at 0° C. as 2.537 grammes, the available calorific value of hydrogen as 29,629 kilogramme calories, and that of carbon as 8,080 kilogramme calories, it is evident that the practical fuel values of hydrogen and natural gas as compared with carbon are respectively as follows: 1 cubic foot of hydrogen equals, practically, 9.30 grammes of carbon; 1 cubic foot of natural gas equals, practically, 20.525 grammes of carbon; therefore, 1,000 cubic feet of natural gas equal 20,525 grammes, or 45.3 pounds of carbon, which is practically equal to 50 pounds of coke carrying 10 per cent of ash.

As the temperature of the natural gas when burned was 16.18° C. instead of 0° C., it is necessary to adjust the value by calculation. This being done it is found that 1,000 cubic feet of natural gas at 16.18° C. have a fuel value of, practically, 47 pounds of coke. Therefore, a ton of coke carrying 10 per cent of ash has a fuel value of, practically, 42,500 cubic feet of an average sample of Stockton natural gas.

The following samples of gas from Wells No. 2 and No. 5 were analyzed by Messrs. Price & Son, of San Francisco, who have kindly placed the results of the analyses at the disposal of the writer. The gas was conveyed in rubber bags from Stockton to San Francisco, and analyzed immediately on its arrival in the latter city. Messrs. Price & Son stated that in these analyses all the hydrocarbon illuminants were estimated as marsh gas:

	Well No. 2.	Well No. 5.
Sample taken—Specific gravity referred to air	0.612	0.607
Marsh gas (CH_4)	60.47 per ct.	62.93 per ct.
Hydrogen (H_2)	11.87 per ct.	11.51 per ct.
Oxygen (O_2)	1.00 per ct.	.70 per ct.
Nitrogen (N_2)	26.66 per ct.	24.36 per ct.
Carbonic di-oxide (CO_2)	trace.	.50 per ct.
Carbonous oxide (CO)	trace.	trace.
	100.00 per ct.	100.00 per ct.

In order to compare the theoretical fuel value of the gas as derived from the analysis, with the practical results obtained by physical experiment, the writer begs to submit the following calculations, the results of which show a wonderful uniformity; indeed, by a curious coincidence, in the case of the gas from Well No. 2, the figures obtained both by analysis and by physical experiment are nearly identical. The calculations, however, are not carried out beyond the third decimal place; and in calculating the results of the physical experiments, the fact that the gas was under a water pressure at 0.6 of an inch is disregarded, as is also the amount of heat lost by the nitrogen shown in the analyses, for the difference occasioned by both these items is less than 1 per cent. In these calculations practical fuel values are taken, namely:

Hydrogen = 29,629 kilo calories.
Carbon = 8,080 kilo calories.
Marsh gas = 11,855 kilo calories.

The figures for marsh gas are the figures of Favre and Silberman, less the latent heat absorbed by converting the hydrogen which the gas contains into water, *i. e.*, 13,063 — 1,208 = 11,855.

Well No. 2.

	Estimated as 1 Cubic Foot.	Weight, in Grammes.	Kilogramme Calories.
Marsh gas (CH_4)	60.47 per ct.	12.350	146.60
Hydrogen (H_2)	11.87 per ct.	0.300 Less 0.05 grammes, required to satisfy 0.406 grammes of O = 0.25 grammes of available H.	7.40
Oxygen (O_2)	1.00 per ct.	0.45	
Nitrogen (N_2)	26.66 per ct.	0	
Carbonic di-oxide (CO_2)	trace.		
Carbonous oxide (CO)	trace.		
	100.00 per ct.		154.00

Thus it is found that one cubic foot of natural gas from Well No. 2 has a fuel value of 154 kilogramme calories. Taking one gramme of carbon as having a fuel value of 8.08 kilo calories, one cubic foot of sample has a fuel value of 19.05 grammes of carbon. Therefore, 1,000 cubic feet of this gas is practically equal to 42 pounds of carbon, or 46 pounds of coke carrying 10 per cent of ash.

Fuel Value of Natural Gas from Well No. 2, as Determined by Physical Experiment.—One cubic foot of this gas, its temperature being 13.2° C., raised the water in the boiler 16.33° C. If the temperature of the gas had been 0° C., one cubic foot of natural gas would have raised the water in the boiler 17.11° C. One cubic foot of hydrogen at 0° C. has a fuel value of 9.3 grammes of carbon. One cubic foot of hydrogen at 0° C. was found to raise the water in the boiler 8.44° C. Therefore, one cubic foot of gas from Well No. 2, its temperature being 0° C., has a fuel value of 18.85 grammes of carbon; and 1,000 cubic feet of this gas have a fuel value of 41.6 pounds of carbon, or practically 1,000 cubic feet of the gas have a fuel value of 46 pounds of coke carrying 10 per cent of ash.

Well No. 5.

	Estimated as 1 Cubic Foot.	Weight, in Grammes.	Kilogramme Calories.
Marsh gas (CH_4)	62.93 per ct.	12.850	152.336
Hydrogen (H_2)	11.51 per ct.	0.292 Less 0.35 grammes, required to satisfy 0.284 grammes of O = 0.257 grammes of available H.	7.614
Oxygen (O_2)	0.70 per ct.	0.284	
Nitrogen (N_2)	24.36 per ct.		
Carbonic di-oxide (CO_2)	0.50 per ct.		
Carbonous oxide (CO)	trace.		
	100.00 per ct.		159.950

Thus we find that the total number of kilo calories in 1 cubic foot of gas from Well No. 5 was practically 160. Therefore, 1 cubic foot of this gas is equal to 19.81 grammes of carbon, and 1,000 cubic feet have a fuel value of 43.6 pounds of carbon, which is practically equal to 48 pounds of coke carrying 10 per cent of ash.

Fuel Value of Natural Gas from Well No. 5, as Determined by Physical Experiment.—One cubic foot of gas from Well No. 5, its temperature being estimated as 0° C., would raise the water in the boiler 18.89° C. One cubic foot of hydrogen at 0° C. would raise the water in the boiler 8.44° C. Therefore, 1 cubic foot of gas from Well No. 5 has a fuel value of 2.238 cubic feet of hydrogen. As the available fuel value of 1 cubic foot of hydrogen equals that of 9.3 grammes of carbon, it follows that 1 cubic foot of gas from Well No. 5 has a fuel value of 20.81 grammes of carbon. One thousand cubic feet of the gas have, therefore, a fuel value of 45.88 pounds of carbon, or practically 50 pounds of coke carrying 10 per cent of ash.

A comparison of the results of the physical experiments on the Stockton natural gas made by the State Mining Bureau, with the theoretical fuel values calculated from the analyses made by Messrs. Price & Son, shows as follows:

From Physical Experiment.	*Calculated from Analysis.*
1,000 cubic feet of an average sample of Stockton natural gas = 50 lbs. of coke.	1,000 feet from Well No. 2 = 46 lbs. of coke.
Sample of Well No. 2 = 46 lbs. of coke.	1,000 feet from Well No. 5 = 48 lbs. of coke.
Sample of Well No. 3 = 50 lbs. of coke.	

In the above calculation the gas is estimated at 0° C., and 0.6 of an inch water-pressure. The standard of comparison is coke carrying 10 per cent of ash.

It is interesting to review the facts and figures with regard to the actual cash value of the Stockton gas wells. The well at the court-house in Stockton is 1,917 feet deep, and together with the gasometer and necessary plant, cost $12,000. The yield of this well is estimated at 30,000 cubic feet of gas daily. Estimating the temperature of the gas at 15° C., the well at Stockton court-house yields, in round figures, $6 10 worth of gas daily, or $2,226 50 worth of fuel a year. This calculation is based simply on the average calorific power of the gas.

It is probably a conservative estimate if we say that the relative depth and yield of the Stockton gas wells range from that of wells a little more than 1,000 feet deep, which yield about 2,500 cubic feet of gas daily, to that of the deepest well at Stockton, which is said to be about 2,600 feet deep, and to yield nearly 80,000 cubic feet of gas a day.

The gas-yielding formations of the San Joaquin and Sacramento Valleys are in proximity to the mines of the Sierra, to beds of pottery clay and of sand suitable for the manufacture of glass. The localities where the principal wells are situated possess water communication with the harbor of San Francisco. It needs no stretch of the imagination to appreciate the fact that natural gas is an important factor in the geological economics of the Central Valley of California.

ESTIMATION OF FUEL VALUE OF NATURAL GAS AT SACRAMENTO, AND ALSO IN KERN COUNTY.

Subsequently to making the experiments on the fuel value of the Stockton natural gas, the writer determined the fuel value of the natural gas from the old gas well at Sacramento, from a gas-yielding spring on the Barker ranch in Kern County, and from a well in the Sunset Oil District, also in Kern County. In all these experiments the same method and apparatus were employed as were used in the determination made of the fuel value of the Stockton natural gas.

The following record of these experiments is self-explanatory to those who have followed the description of the experiments made at Stockton:

Name of Well.	Barometric Height Approximated by a Pocket Aneroid	Amount of Gas Burned	Temperature of Gas	Average Temperature of Air	Temperature of Water at Beginning of Experiment	Temperature of Water at End of Experiment
		Cu. Ft.				
Old gas well at Sacramento	29.52 in.	3	18.0° C.	17.85° C.	15.00° C.	50.25° C.
Average of four experiments at gas-yielding spring, Barker Ranch, Kern County	29.00 in.	3	23.5	23.75	19.50	80.00
Gas well in Sec. 28, T. 11 N., R. 23 W., S. B. M. (Sunset Oil District, Kern County)	28.75 in.	3	31.5	32.00	26.75	80.12

Name of Well.	Number of Degrees Water was Raised	Number of Degrees for Each Foot of Gas Burned	Duration of Experiment	Open Pressure of Gas in Meter	Average Temperature at which Products of Combustion were Lost	Loss by Radiation and Conduction, Approximated Experimentally.
			Minutes.	Inch of Water.		
Old gas well at Sacramento	35.25° C.	11.750°C.	40.5	.6	31.00°C.	....
Average of four experiments at gas-yielding spring, Barker Ranch, Kern County	61.00	20.225	63.0	.6	43.00	2.25°C.
Gas well in Sec. 28, T. 11 N., R. 23 W., S. B. M. (Sunset Oil District, Kern County)	53.38	17.790	65.0	.6	46.25	1.23

Repeated preliminary experiments with the natural gas from the old gas well at Sacramento showed that the best results were obtained by partially closing the air passages at the base of the jets in the Bunsen burner. Repeated experiments with the natural gas at the Barker Well and at the Sunset Oil District showed that, with the burner used, it was impossible to burn the gas economically and faster than at the rate of consumption employed, for a very slight increase in the pressure or the supply of gas made the flame roar.

Taking the fuel value of the Stockton natural gas at a temperature of 16.18° C. as a basis of calculation, we obtain, in round figures, by the methods of calculation heretofore employed, the following fuel values: 2,000 pounds of coke carrying 10 per cent of ash equals 42,500 cubic feet of an average sample of Stockton natural gas; or 63,000 cubic feet of gas from the old gas well at Sacramento; or 36,000 cubic feet of gas from the gas-yielding spring on the Barker ranch in Kern County; or 40,000 cubic feet of natural gas from the well in Sunset Oil District in Kern County.

A comparison of the descriptions of the Stockton and Sacramento gas wells shows that the well from which the gas used in the experiments at Sacramento was obtained, is much shallower than are most of the gas wells at Stockton. As premised when speaking of the gas wells at Stockton, the gas from shallow wells which are bored in the filling of a valley is more likely to be diluted with nitrogen or air than gas which is obtained from the deep wells which furnish gas from strata below the principal supply of artesian water. It is possible that the great fuel value of the gas from the spring on the Barker ranch results from a large amount of sulphuretted hydrogen being present; for although the calorific value of the latter gas is low, its specific gravity is more than double that of marsh gas, and in the experiments cited in this article, the gases used were measured volumetrically. Some sulphuretted hydrogen was also noticeable in the gas from the well in the Sunset Oil District.

The following comparison of the wells from which the gas used in the foregoing experiments was obtained, and the fuel value of the gas which they respectively yield, is not without interest:

Name of Well.	Depth of Well.	Fuel Value of Gas.	Remarks.
The Stockton wells..	1,350 to about 2,600 feet.	42,500 cu. ft. = 2,000 lbs. of coke carrying 10 per cent of ash.	These wells appear to penetrate the recent and Quaternary filling of the San Joaquin Valley for more than 1,000 feet.
Old gas well at Sacramento.	875 feet......	64.000 ~~63,000~~ cu. ft. = 2,000 lbs. of coke.	For the first 500 feet this well appears to penetrate the recent and Quaternary filling of the Sacramento Valley; whether or not the harder material penetrated below that depth belongs to an older formation there is no evidence to determine.
Gas from the spring at the Barker ranch, Kern County.	....	36,000 cu. ft. = 2,000 lbs. of coke.	This spring issues from Tertiary rocks.
Gas from well in Sec. 28, T. 11 N., R. 23 W., S. B. M., in Sunset Oil District, Kern County.	1,350 feet......	40,000 cu. ft. = 2,000 lbs. of coke.	

The conditions under which the experiments herein recorded were performed were rendered as uniform as circumstances would permit; indeed, they were more uniform than the conditions would have been had the gas been burned at the different localities under the ordinary conditions attending the utilization of gas for the production of steam, or for other manufacturing purposes. Therefore, differences resulting from barometric pressure, and radiation, etc., have been disregarded, since they would only burden the article with calculations, without materially affecting the results. With regard to the temperature of the gases, however, the various temperatures have been reduced by calculation to 0° C. wherever hydrogen is taken as a standard of fuel value. Wherever the standard of comparison is the average sample of Stockton natural gas, a common temperature of 16.18° C. is employed, for the latter figures represent the average temperature at which the experiments were conducted in Stockton.

The reader will gather some idea of the parity of the conditions attending the different experiments herein recorded, by carefully inspecting and comparing the figures given in the accompanying tables, wherein the conditions attending the various experiments are noted. The apartments in which the experiments were made with hydrogen at San Francisco, and with natural gas at Stockton and Sacramento, were practically free from draft, and the prevailing temperatures of the air, and probably of the walls of those apartments, exhibited a difference of less than 3° C. The mean temperatures reached by the water in the experiments in Stockton and San Francisco, after deducting the temperatures of the air, also exhibited no greater difference. It follows, therefore, that the loss by radiation and conduction would be very similar in the experiments made at these places. The mean temperature reached by the water in the experiments at Sacramento, after deducting the temperature of the air, was considerably less than was the case in the experiments at Stockton and San Francisco. Other things being equal, it follows, therefore, that the loss of heat by radiation and conduction in the experiments made at Sacramento would be less than in those made at Stockton and San Francisco. In the experiments made at the Barker ranch and at the Sunset Oil District, the temperatures of both water and air were higher than was the case in the previous experiments. The loss of heat by radiation and conduction was therefore approximately estimated by experiment in each of those places; and it proved to be very nearly the same as it was in the experiment with hydrogen.

The method employed to approximate the loss by radiation and conduction was the same at San Francisco, the Barker ranch, and the Sunset Oil District. It was as follows: Immediately after making the experiments to determine the fuel value of a sample of gas, a boilerful of water was heated to a temperature equal to the temperature of the air, plus half the number of degrees that the water had been raised above the temperature of the air in the corresponding fuel-value experiments. The boilerful of heated water was then allowed to cool for a time equal to the time occupied by the respective fuel-value experiments, and the amount of heat lost was noted. An examination of the before mentioned tables shows that the difference in the temperature of the air in the fuel-value experiments was compensated by the difference in temperature at which the products of combustion were lost. It must also be noticed that the fuel value obtained for the natural gas at the Barker ranch and the Sunset Oil District, as compared with that obtained for the other samples of gas tested, was slightly lessened by the barometric pressure being a little less at the Barker ranch and at the Sunset Oil District, than it was at Stockton, Sacramento, or San Francisco.

COMPARISON OF STOCKTON NATURAL GAS WITH NATURAL GAS IN EASTERN STATES.

Let us now compare the fuel value of the Stockton gas with the fuel value of samples of natural gas from wells in the Eastern States.

The following analyses were made by S. A. Ford, Chemist to the Edgar Thomson Steel Works, Pennsylvania, as quoted in "Chemical Technology," by Groves and Thorp, vol. 1, p. 290:

Analyses of Natural Gas.

	No. 1.	No. 2.	No. 3.
When tested	Oct. 28, 1884.	Oct. 29, 1884.	Nov. 24, 1884.
Carbonic di-oxide (CO_2)	.80 per ct.	.60 per ct.	nil.
Carbonous oxide (CO)	1.00 per ct.	.80 per ct.	.58 per ct.
Oxygen (O_2)	1.10 per ct.	.80 per ct.	.78 per ct.
Olefiant gas (C_2H_4)	.70 per ct.	.80 per ct.	.98 per ct.
Ethylic hydride (C_2H_6)	3.60 per ct.	5.50 per ct.	7.92 per ct.
Marsh gas (CH_4)	72.18 per ct.	65.25 per ct.	60.70 per ct.
Hydrogen (H_2)	20.02 per ct.	26.16 per ct.	29.03 per ct.
Nitrogen (N_2)	nil.	nil.	nil.
Heat units (in 100 liters)	728.746 ~~per~~ ct.	698.752 ~~per~~ ct.	627.170 ~~per ct.~~

	No. 4.	No. 5.	No. 6.
When tested	Dec. 4, 1884.	Oct. 18, 1884.	Oct. 25, 1884.
Carbonic di-oxide (CO_2)	.40 per ct.	nil.	.30 per ct.
Carbonous oxide (CO)	.40 per ct.	1.00 per ct.	.60 per ct.
Oxygen (O_2)	.80 per ct.	2.10 per ct.	1.20 per ct.
Olefiant gas (C_2H_4)	.60 per ct.	.80 per ct.	.60 per ct.
Ethylic hydride (C_2H_6)	12.30 per ct.	5.20 per ct.	4.80 per ct.
Marsh gas (CH_4)	49.58 per ct.	57.85 per ct.	75.16 per ct.
Hydrogen (H_2)	35.92 per ct.	9.64 per ct.	14.45 per ct.
Nitrogen (N_2)	nil.	23.41 per ct.	2.89 per ct.
Heat units (in 100 liters)	745.813 ~~per ct.~~	592.380 ~~per ct.~~	745.591 ~~per ct~~.

It is here assumed that these heat units are similar to the heat units used by the author quoted, when, in another paragraph of the work referred to, he estimates the fuel value of an average sample of natural gas. The first four samples were taken from the same well on the day that the gas was analyzed; the last two are from different wells in the East Liberty District. Referring to various authorities, it is found that the foregoing figures fairly represent the average composition of the Eastern natural gas, and it is evident that the greatest factor in influencing the fuel value is the amount of nitrogen present.

In the before-mentioned work on fuels, Mr. Ford is quoted as saying: "I have found that gas from the same well continually varies in composition. Thus, samples of gas from the same well, but taken at different days, varied in nitrogen from 23 per cent to nil; in carbonic acid, from 2 per cent to nil; in oxygen, from 4 per cent to 0.4 per cent, and so on with all the component gases."

In the same work it is stated that an average sample of Eastern natural gas has approximately the following composition:

Carbonic di-oxide (CO_2)	0.60 per cent.
Carbonous oxide (CO)	0.60 per cent.
Oxygen (O_2)	0.80 per cent.
Olefiant gas (C_2H_4)	1.00 per cent.
Ethylic hydride (C_2H_6)	5.00 per cent.
Marsh gas (CH_4)	67.00 per cent.
Hydrogen (H_2)	22.00 per cent.
Nitrogen (N_2)	3.00 per cent.

The same author goes on to show that 100 liters of this gas contain 789,694 heat units, and he states that 64.8585 grammes of carbon have a calorific value equal to 524,046 of these units, and that 1,000 cubic feet of the average sample of natural gas have a fuel value equal to that of 62.97 pounds of coke carrying 10 per cent of ash.

Carrying the calculation a little further, and allowing for the latent heat of steam, which it is necessary to do in order to compare the relative fuel values of the Eastern and of the Stockton gases under the conditions attending the combustion of the gas in the experiments at Stockton, and which usually attends the combustion of gas in practical use, we find that in round figures 1,000 cubic feet of the average sample of Eastern gas has a fuel value equal to that of 58 pounds of coke carrying 10 per cent of ash.

Taking the average sample of Stockton gas as having a fuel value of 1,000 feet equal to that of 50 pounds of coke, such as that to which Mr. Ford compared the Eastern gas, we find that the fuel value of the Stockton gas is about 16 per cent less than that of the sample of Eastern gas above estimated. We also find by referring to the analyses of the Stockton gas, made by Price & Son, that this difference in fuel value is principally occasioned by the amount of nitrogen present. If we compare the heat units as given for 100 liters of the average sample of Eastern natural gas with the heat units given for 100 liters of sample No. 5 of Eastern gas analyzed by Mr. Ford, we find that sample No. 5 has a fuel value practically equal to that of 47 pounds of coke for every 1,000 cubic feet of the gas. Research shows that gases containing a high per cent of nitrogen are by no means uncommon in the Eastern States, and that large industries have been developed on account of natural gas, which from existing data may be inferred to have an average fuel value not much in excess of that of the Stockton natural gas. It is to be borne in mind that large volumes of water flow from the gas wells at Stockton; and it is probable that the nitrogen is largely derived from the air which is drawn down with the water when it sinks into the ground at the head of the artesian system. This air is most likely deoxygenized by ferrous iron or other bases as it accompanies the water in its journey to a lower level; the result being, that a large amount of nitrogen is liberated with the water from the artesian wells. We may conclude from these considerations that if the water were shut off, and the gas obtained from lower strata, not only would the flow of gas be enormously increased, but its quality improved. It is also probable that were the wells tightly cased so as to shut off both gas and water for the first 1,500 feet, much of the nitrogen would be excluded.

It is interesting to note the comparison between the Stockton natural gas and other gases which are used as fuel. The analyses of five samples of the Siemen's producer gas, as given in the "Transactions of the

American Institute of Mining Engineers," and quoted in "Chemical Technology," by Grove and Thorp, vol. 1, is as follows:

	a	*b*	*c*	*d*	*e*
Carbonic di-oxide (CO_2)	3.9 per ct.	9.3 per ct.	1.5 per ct.	6.1 per ct.	8.6 per ct.
Carbonous oxide (CO)	27.3 per ct.	16.5 per ct.	23.6 per ct.	22.3 per ct.	20.0 per ct.
Hydrogen (H_2)	....	8.6 per ct.	6.0 per ct.	28.7 per ct.	8.7 per ct.
Marsh gas (CH_4)	1.4 per ct.	2.7 per ct.	3.0 per ct.	1.0 per ct.	1.2 per ct.
Nitrogen (N_2)	67.4 per ct.	62.9 per ct.	65.9 per ct.	41.9 per ct.	61.4 per ct.

Assuming that these percentage compositions are volumetric, and eliminating the smaller fractions, we obtain by the methods of calculation heretofore employed in this article, the following equivalents of fuel value:

1,000 cubic feet of sample *a* = 8.0 lbs. of coke carrying 10 per cent of ash.
1,000 cubic feet of sample *b* = 8.2 lbs. of coke carrying 10 per cent of ash.
1,000 cubic feet of sample *c* = 9.6 lbs. of coke carrying 10 per cent of ash.
1,000 cubic feet of sample *d* = 13.0 lbs. of coke carrying 10 per cent of ash.
1,000 cubic feet of sample *e* = 8.0 lbs. of coke carrying 10 per cent of ash.

The average fuel value, therefore, of these samples of producer gas is 1,000 cubic feet, equal to, practically, 9.3 pounds of coke carrying 10 per cent of ash.

A description of by far the best producer gas of which the writer can find any record is to be found in "Grove and Thorp's Chemical Technology," vol. 1, pp. 261–285. It is there stated as follows:

"The best quality of (producer) gas obtained in practice seems to have been that produced by the Strong water gas apparatus. The following is an analysis of the dry gas, after having been washed, made by Dr. G. E. Moore, of Jersey City, for the American Gas, Fuel, and Light Company, New York, who own the patent for the Lowe and Strong apparatus:

"Strong" Gas Composition by Volume.

Oxygen (O_2)	0.77 per cent.
Carbonic di-oxide (CO_2)	2.05 per cent.
Nitrogen (N_2)	4.43 per cent.
Carbonous oxide (CO)	35.88 per cent.
Hydrogen (H_2)	52.76 per cent.
Marsh gas (CH_4)	4.11 per cent.
	100.00 per cent.

From this formula we find by calculation that 1,000 cubic feet of this gas have a fuel value practically equal to that of 23.9 pounds of coke carrying 10 per cent of ash. In this estimation it is assumed that the oxygen in the "dry gas" was free; if it were combined with hydrogen, about half a pound of coke would have to be deducted from the coke equivalents given.

In the "Transactions of the American Institute of Mining Engineers," vol. 19, we find the following remarks on producer and petroleum water gas. Referring to the producer gas, two average samples are quoted which were the products of the following processes:

Method A.—Open grates; no steam in blasts. Loss of carbon in ash, 20 per cent weight of coal. Carbon gasified 62 per cent weight of coal. Loss of potential heat in ash per kilo of coal, 1,616 kilo calories.

Method B.—Open grates; steam jet in blast. Loss of carbon in ash, 6 per cent weight of coal. Loss of potential heat in ash per kilo of coal, 4,848 kilo calories.

Analysis of Producer Gas. (Calculated as one cubic foot.)

	CO_2	O_2	C_2H_4	CO	H_2	CH_4	N_2
Sample A	4.84	0.40	0.34	22.10	6.80	3.74	61.73
Sample B	5.30	0.54	0.36	22.74	8.37	2.56	60.13

We find that 1,000 cubic feet of sample A has a fuel value practically equivalent to 10.2 pounds of coke carrying 10 per cent of ash, and that the fuel value of 1,000 feet of sample B equals 9.7 pounds of similar coke.

Referring to petroleum water gas, the same records state that "the following are analyses of various gases taken from furnace using oil fuel":

Sample of Gas taken after passing through Checkers.

	CO_2	C_2H_4	O_2	CO	H_2	CH_4	N_2
No. 1	4.6	0.0	1.8	9.6	51.6	0.4	24.0
No. 2	5.6	0.4	2.0	11.2	51.8	7.2	21.8
No. 3	4.4	0.0	4.0	6.4	42.2	7.0	36.0
No. 4	6.6	0.0	0.6	10.0	37.3	7.6	37.9
No. 5	4.0	7.6	2.0	5.4	44.1	22.1	17.0
No. 6	4.0	7.6	2.0	5.4	46.5	23.1	11.4
No. 7	4.4	3.6	2.4	6.0	44.4	19.0	20.2

Undecomposed steam		
	Sample 1	240 grammes per C. M.
	Sample 2	122 grammes per C. M.

The oil gas referred to in these analyses was made by vaporizing crude petroleum by a jet of superheated steam and heating the mixture to 300° or 400° C. If such a mixture of vapors is put into the hot chamber of a regenerative furnace, the reaction caused by the high temperature, thorough mixing, and impact, creates permanent gases with decomposition of carbon. The steam brings with it some oxygen and nitrogen, which are dissolved in the water in the boilers, and this oxygen, together with that of the steam, tends to pick up the deposit of carbon with liberation of hydrogen.

It will be noticed that the foregoing analyses of petroleum water gas show a wide variation of composition. The first four samples were taken after the gas had traversed about 5 feet of open hearth checker-work at a temperature of 1,200° C. The last three samples were taken after it had passed through 3 feet of heating furnace in checker-work at a much lower temperature, and represent the oil vapors in various stages of decomposition. The presence of so much free oxygen, the high per cent of carbonic di-oxide, and the large amount of steam when considered in connection with carbonaceous components, illustrate plainly the fact that a long time and high temperature are necessary for the completion of the reactions incident to the gasification of oil fuel.

The average composition of the samples of the petroleum water gas mentioned is therefore as follows:

	CO_2	C_2H_4	O_2	CO	H_2	CH_4	N_2
From the first four samples of fixed gas	5.30	0.10	2.10	9.30	45.72	7.55	29.92
From the last three samples	4.13	5.73	1.93	5.60	45.00	21.40	16.20

By calculation it is found that 1,000 cubic feet of gas representing the average of the first four samples of petroleum water gas have a fuel value of practically 17.4 pounds of coke carrying 10 per cent of ash. In like manner, it is seen that an average sample representing the last three samples of petroleum water gas have a fuel value practically equal to that of 33 pounds of coke carrying 10 per cent of ash.

Having reviewed to some extent the composition and fuel value of California and Eastern natural gas and producer and petroleum water gas, it is interesting to compare them with a gas made by the destructive distillation of coal before the introduction of producer and petroleum water gases.

Let us take the analysis made by Bunsen of gas prepared from Cannel coal in Manchester, England, calculated as one cubic foot. (See Bunsen's Gasometry, p. 113.)

Hydrogen (H_2)	45.48 per cent.
Marsh gas (CH_4)	34.90 per cent.
Carbonous oxide (CO)	6.64 per cent.
Elayl (C_4H_4)	4.08 per cent.
Ditetryl (C_8H_8)	2.38 per cent.
Sulphuretted hydrogen (H_2S)	.29 per cent.
Nitrogen (N_2)	2.46 per cent.
Carbonic di-oxide (CO_2)	3.67 per cent.
	100.00 per cent.

By calculation it is found that 1,000 cubic feet of this gas have, in round numbers, a fuel value of 51 pounds of coke carrying 10 per cent of ash.

Disregarding fractions, the gases thus far considered represent the following fuel values, as compared with coke carrying 10 per cent of ash.

Eastern natural gas (considered by Mr. Ford to be of average composition)	Fuel value = 58 lbs. of coke.
Sample of Manchester coal gas	Fuel value = 51 lbs. of coke.
Average of Stockton gas	Fuel value = 50 lbs. of coke.
Sample of natural gas No. 5, from East Liberty, Pa.	Fuel value = 47 lbs. of coke.
Petroleum water gas before becoming a fixed gas, described in the "Transactions of the American Institute of Mining Engineers," vol. 19.	Fuel value = 33 lbs. of coke.
Petroleum water gas as a fixed gas (from same authority)	Fuel value = 17 lbs. of coke.
Water gas from analysis made for the owners of the Lowe & Strong patents	Fuel value = 24 lbs. of coke.
Siemens producer gas, from average of analyses	Fuel value = 9 lbs. of coke.
Sample A, producer gas, referred to in the "Transactions of the American Institute of Mining Engineers," vol. 19	Fuel value = 10 lbs. of coke.
Sample B (from same authority)	Fuel value = 9 lbs. of coke.

In the calculations on which the above figures are based, the writer estimated the gases as possessing a temperature of 0° C., and as being subjected to a pressure of one atmosphere. He disregarded the fact that in his physical experiments with natural gas at Stockton the gas was measured under a pressure of six-tenths of an inch of water; for the increase in the fuel value of the gas resulting from so slight a pressure would be less than a quarter of one per cent.

The coke to which the gases mentioned in this article are compared is supposed to have a composition of carbon 90 per cent and ash 10 per cent.

RELATIVE FUEL VALUE OF STOCKTON NATURAL GAS AND PACIFIC COAST SOLID FUELS.

The reader will doubtless be curious to learn how the Stockton natural gas compares in fuel value with the solid fuels obtainable on the Pacific Coast. Unfortunately the writer has been unable to find any ultimate analyses of California coals, although numerous proximate analyses have been made. In the Census Reports on Mining, however, there are both the ultimate and proximate analyses of several samples of coals and lignites from the State of Washington. With this data at command there is submitted for comparison the proximate analyses of coals to be found in the market of California, and the average composition of coal and lignites from Washington, which the writer has calculated from the proximate and ultimate analyses given in the Census Report on Mining. Moreover, by means of the ultimate analyses of the coal and lignites from Washington, the caloric value of these solid fuels can be compared with the Stockton natural gas.

Analyses of some Coals and Lignites used in California.

	Water.	Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.
Sample of coal from California Mine, Fresno County. (Analyzed by Dr. W. D. Johnston, Chemist to the California State Mining Bureau)	11.25	48.50	31.40	8.85	----------
Ione coal, from Mine No. 3 of Ione Coal and Iron Co. (Analyzed by Dr. W. D. Johnston)	13.25	49.00	27.25	10.50	----------
Mount Diablo coal, Black Diamond vein. (As given in State Geological Survey Report, Geology of California, vol. 1, p. 30)	14.68	33.89	46.84	5.52	----------
Seattle coal, average of two samples. (Analyzed by Mr. H. G. Hanks; see VIIth Report of California State Mining Bureau)	9.18	36.90	46.99	6.46	---------
Wellington coal. (Analyzed by Messrs. Price & Son)	0.99	29.09	64.97	3.51	1.44

Referring to the Tenth Census Report, Vol. XV, and the proximate analyses of coals and lignites as given therein, we find that samples 11, 12, 19, 20, 21, 33, 34, 35, 36, 37, 64, and 65 are coking coals, although in three instances the coke does not appear to have any value. We also find that samples 68, 69, 71, 80, 47, 23, 25, and 26 are non-coking coals, or coals of which the coke is worthless. By calculation from the data given in the census report, we obtain the following average compositions:

From Proximate Analyses of Coals and Lignites from Washington.

	Water.	Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.
Coking coal	1.70	31.28	54.11	12.90	0.65
Non-coking coal	3.23	32.32	52.15	12.36	0.53

From Ultimate Analyses of the Combustible Matter Contained in Same Samples.

	Carbon.	Hydrogen.	Oxygen and Nitrogen.
Coking coal	83.31	5.26	11.43
Non-coking coal	82.52	4.81	12.66

Regarding the water, ash, and sulphur in these average samples as inert, for the calorific effect of the sulphur is offset by the heat required to convert the hygroscopic water into steam, it is found by calculation that the relative fuel value of these samples of coal is practically as follows:

Sample of non-coking coal = 6,977 kilo calories per kilogramme.
Sample of coking coal, = 7,122 kilo calories per kilogramme.

Referring to "Chemical Technology," by Groves & Thorp, vol. 1, p. 57, the analyses of the ten samples of anthracite were given. As in the case of the Washington coals, the writer, for the purpose of estimating the fuel value, calculated the average composition of the ten samples, and found it to be practically as follows:

Carbon	89.88 per cent.
Hydrogen	2.80 per cent.
Oxygen, nitrogen, and sulphur	4.01 per cent.
Ash	3.63 per cent.

Simply regarding the carbon and hydrogen as the calorific constituents of this average sample of anthracite, it is found by calculation that it possesses a fuel value of practically 8,092 kilo calories per kilogramme.

Referring to the previous calculations with regard to the Stockton natural gas, it can readily be seen that 1,000 feet of that gas at a temperature of 16.18° C. have a fuel value of practically 155,900 kilo calories. Thus it is found that the relative fuel value of the Stockton natural gas and the coals, estimated, is as follows:

1 ton of anthracite = 47,000 cu. ft. of Stockton natural gas.
1 ton of average sample of coking coal from Washington = 41,360 cu. ft. of Stockton natural gas.
1 ton of average sample of non-coking coal from Washington = 40,700 cu. ft. of Stockton natural gas.

In our VIIth Annual Report a short table was published showing the relative fuel value of twelve different kinds of coal which are still in great demand in the California market. The relative fuel values, as shown in the table, are approximate, and were derived from practical experiments by the Spring Valley Water Company, Messrs. Garratt, and others. As the demand for the VIIth Annual Report has long ago exhausted the edition, it will be in order to reproduce the table, and to add thereto a column giving in round figures the number of feet of Stockton gas required to do the same amount of work as could be done by a ton of each variety of coal named. Assuming anthracite to have a fuel value as calculated, and applying its equivalent in Stockton natural gas to the table mentioned, we obtain, in round figures, the following schedule:

Relative Fuel Value of Different Coals as Compared with Each Other, and as Compared to Stockton Natural Gas.

Kind of Coal.	Relative Fuel Value.	Remarks.	Cubic Feet of Gas Equal to 1 Ton of 2,000 lbs. of Coal.
Mt. Diablo	1,000	Experiments at Spring Valley Water Works	30,400
Seattle	1,170		35,570
Sydney	1,502		45,660
Welsh	1,472		44,750
Bellingham Bay	1,148		34,900
Nanaimo	1,277		38,800
Anthracite	1,546		47,000
Wellington	1,407		42,710
Nanaimo	1,335	Exp'ts at Garratt's foundry	40,580
Wellington	1,295		39,370
Seattle	1,177	Experiments on ferry-boat	35,780
Seattle	1,330	Probable results of test on C. P. R. R.	40,430

As might be expected, the variable quality of different consignments of coal and the different conditions attending the last four experiments, occasioned a difference in results; but no doubt the series of tests made by the Spring Valley Water Company afford the most accurate means of comparison, for their experiments appear to have been conducted under approximately similar conditions.

Having compared the relative calorific value of 1,000 feet of Stockton natural gas with that of one ton of an average sample of bituminous coal from Washington, it is found that the gas at 30 cents a thousand cubic feet is as cheap a fuel as the coal would be at $12 30 a ton of 2,000 pounds. If we take the last six samples of bituminous coal used in the practical experiments made at the Spring Valley Waterworks and compare them with their fuel equivalent in gas, about the same figures are obtained as those arrived at by calculation from the analysis of the coal from Washington.

Hitherto we have only considered the value of the natural gas as demonstrated by comparing its calorific value with that of the other fuels. The advantages that manufacturers have experienced by using gas instead of solid fuel should also be considered briefly. It is shown in an able article on natural gas, by Mr. J. D. Weeks, which is published in "Mineral Resources of the United States, 1885," that in the manufacture of flint glass a saving of 46 per cent was effected by using natural gas instead of coal, to which might be added the saving in wear and tear of furnace and in labor; moreover, a better quality of glass was produced than when solid fuel was used. The records of the steel and iron industry are replete with evidence of the saving occasioned by the use of gaseous fuel, especially in the matter of labor.

A great reduction in the amount of "waste iron" has also been noted, and the item of repairs, which is a large one in this industry, is reduced to the minimum. A saving of $3 to the ton of bar iron is regarded as a very conservative estimate where gas is used, as against the production of one ton of bar iron by any other fuel. In this connection much that is said about the advantages to be derived from using producer and petroleum gases will doubly apply in the use of natural gas; and we have already seen how the actual calorific values of these gases compare with one another.

We learn in the "Transactions of the American Institute of Mining Engineers," vol. 19, p. 1005, in speaking of the producer gas, that, even where coal was only $3 a ton, many large firms effected a direct gain of from 33⅓ to 50 per cent in labor, and over 40 per cent in fuel, by the substitution of producer gas for coal. This economy resulted from the gas requiring less labor and the furnace less repairs than was the case when coal was used, and from the fact that the combustion of the gas left no solid residue, nor did it produce deleterious vapors. Other reasons were that the quality of the gas was uniform, and its combustion complete; that the gas was self-transporting, and that it could be ignited under any desired conditions, producing a quick, sharp-heating flame of high temperature.

In the Eastern States it has been estimated that in practical use 20,000 feet of producer gas often accomplished better results than a ton of coal directly fired, although it will be seen by a glance at what has been previously said, that the actual calorific value of 20,000 feet of producer gas is very much less than that of one ton of coal.

The before-mentioned records also state that practical working has shown that in melting 2,000 pounds of brass in 100-pound crucibles, 12,000 feet of water gas were consumed. That in using the same size of crucibles in works melting from 5 to 10 tons of metal a day with coal, it takes 2,000 pounds of coal for 2,000 pounds of brass. This is a striking comparison, since the units of heat in the coal was seven and one half times more than in the gas. It is stated that one ton of coal will make 40,000 feet of water gas, which will accomplish as much as three and a half tons of coal.

It is obvious that the economy experienced by the use of gas in metallurgical industries extends to every manufacture and domestic requirement where heat is needed.

RECORD OF DISTILLATION TESTS OF SAMPLES OF OIL MENTIONED IN THIS BULLETIN.

Sample from Oil Springs on Rathburn Oil Claim, Colusa County.

		Specific Gravity.
Crude oil		0.982, about 13° B.
Distillate below 250° Centigrade	1.00 per cent.	
Distillate between 250° and 325° Centigrade	60.00 per cent.	0.950, about 18° B.

Nearly all of the distillate came over at 300° Centigrade.

Sample from Well No. 3, Group 2, Sec. 28, Sunset Oil District, Kern County.

		Specific Gravity.
Crude oil		0.956, about 17° B.
Distillate below 250° C.	1.00 per cent.	
Distillate below 320° C.	48.33 per cent.	0.876, about 30° B.

Sample from Well No. 2, Group 2, Sunset Oil District.

		Specific Gravity.
Crude oil		0.971, about 14° B.
Distillate below 250° C., about	1.00 per cent.	
Distillate below 325° C.	13.00 per cent.	0.893, about 27° B.

This sample of oil smelled strongly of sulphuretted hydrogen.

Sample from Oil Wells, Group 1, Sunset Oil District.

		Specific Gravity.
Crude oil (maltha)		1.01, about 10° B.
Distillate below 250° C.	0.60 per cent.	
Distillate below 320° C.	40.00 per cent.	0.881, about 29° B.

This sample was obtained from a tank which was said to be filled with a mixture of oils from Oil Wells, Group 1.

Sample from Well near Flowing Well, Sunset Oil District.

		Specific Gravity.
Crude oil		.966, about 15° B
Distillate below 200° C.	0.60 per cent.	.840, about 37° B.
Distillate below 250° C.	5.00 per cent.	.845, about 36° B.
Distillate below 300° C.	8.60 per cent.	.870, about 31° B.
Distillate below 320° C.	5.20 per cent.	.875, about 30° B.

Sample from Oil Well penetrating Dark-Colored Shale Formation Nine Miles North of Coalinga.

		Specific Gravity.
Crude oil		.852, about 34° B.
Distillate below 110° C.	0.60 per cent.	
Distillate below 150° C.	32.00 per cent.	.799, about 45° B.
Distillate below 200° C.	27.60 per cent.	.833, about 38° B.
Distillate below 250° C.	16.60 per cent.	.875, about 30° B.
Distillate below 320° C.	12.00 per cent.	.911, about 24° B.

The well from which this sample of oil was taken penetrates Cretaceous formations.

Sample of Oil (Maltha) from Spring in Oil District South of Coalinga.

		Specific Gravity.
Crude oil		.974, about 14° B
Distillate below 250° C. (came over with water)	1.00 per cent.	
Distillate below 320° C.	2.30 per cent.	.820, about 41° B.

Sample from Oil Spring in Light-Colored Shales, Nine Miles North of Coalinga.

		Specific Gravity.
Crude oil		.988, about 12° B.
Below a temperature of 200° C. a small amount of oil came over with water.		
Distillate below 250° C.	2.30 per cent.	
Distillate below 320° C.	6.20 per cent.	.961, about 16° B

Sample from Well in Vallecitos.

		Specific Gravity.
Crude oil		.975, about 14° B
Distillate below 250° C.	1.43 per cent.	
Distillate below 320° C.	9.00 per cent.	.886, about 32° B

PARTIAL ANALYSES OF SAMPLES OF WATER REFERRED TO IN THIS BULLETIN.

In order to determine whether or not the water from the wells mentioned in the foregoing pages is of any value as brine, the following partial analyses were made. In these determinations the residues were subjected to sufficient heat to get rid of any hydrocarbons present without decomposing the carbonate of lime:

Water from Well No. 3, Oil Wells Group 2, Sunset Oil District.

Amount of sample required to neutralize one gramme of sulphuric acid, 2,766 cc.

	Grammes to Gallon.
Total residue	138.840
Amount of residue soluble in water	137.050
Partial analysis of soluble residue:	
Sodium chloride	118.095
Calcium chloride	16.375
Magnesium chloride	2.480
Iodine	0.075

The portion of the residue which was insoluble in water effervesced, and nearly dissolved when treated with cold dilute hydrochloric acid. The portion soluble in water showed the presence of sulphates and carbonates in very small quantities.

Water from Well No. 2, Oil Wells Group 2, Sunset Oil District.

Amount of sample required to neutralize one gramme of sulphuric acid, 818 cc.:

	Grammes to Gallon.
Total residue	40.77
Amount of residue soluble in water	38.800

Partial analysis of soluble portion:

Sodium chloride	33.521
Magnesium chloride	1.880
Magnesium sulphate	1.668
Calcium sulphate	1.431

This sample smelled strongly of sulphuretted hydrogen. The portion of the residue which was insoluble in water effervesced and nearly dissolved when treated with cold dilute hydrochloric acid. The portion soluble in water also showed the presence of alkaline carbonates.

50 cc. of this sample, when concentrated to 10 cc., gave a strong reaction for iodine.

Water from Well in Section 13, T. 11 N., R. 24 W., S. B. M., Sunset Oil District, Kern County.

Amount of sample required to neutralize one gramme of sulphuric acid, 127 cc.

	Grammes to Gallon.
Total residue	73.332
Amount of residue soluble in water	71.712

The portion of the residue which was soluble in water contained 54.81 grammes of sodium chloride to the gallon calculated from the amount of chlorine present. Only very small quantities of calcium and magnesium were found in this portion of the residue, which also showed traces of sulphates and large amounts of alkaline carbonates without concentration; this sample gave a slight reaction for iodine.

Sample from Spring near Flag 6, Sunset Oil District. (See sketch-map.)

Amount of sample required to neutralize one gramme of sulphuric acid, 446 cc.

	Grammes to Gallon.
Total residue	28.365
Amount of residue soluble in water	22.270

The soluble portion of the residue contained 10.58 grammes of sodium chloride to the gallon, calculated from the amount of chlorine present. Only very small quantities of calcium and magnesium were found in this portion of the residue, which also contained sulphates and alkaline carbonates. This sample smelled strongly of sulphuretted hydrogen.

Sample from Well at Salt Marsh, Sunset Oil District.

Amount of sample required to neutralize one gramme of sulphuric acid, 305 cc.

	Grammes to Gallon.
Total amount of residue	46.645
Amount of residue soluble in water	43.300

The soluble portion of this residue contained 37.44 grammes of sodium chloride to the gallon. Only very small amounts of calcium and magnesium were found in this portion of the residue, which also showed the presence of sulphates in small quantities, and alkaline carbonates. 100 cc. of this water, when boiled down to 10 cc., gave a strong reaction for iodine. Sample smelled of sulphuretted hydrogen.

Sample from the Flowing Well in the Oil District Nine Miles North of Coalinga.

Amount of water required to neutralize one gramme of sulphuric acid, 932 cc.

	Grammes to Gallon.
Total residue	66.64
Amount of residue soluble in water	64.00

Partial analysis of soluble portion of residue:

Sodium chloride	58.030
Calcium	1.135
Magnesium	4.648

When 50 cc. of this sample were concentrated to 10 cc., a strong reaction for iodine was obtained; traces of sulphates and small quantities of the alkaline carbonates were also present in the water. A sample of water which was subsequently obtained from this well was found to contain 0.016 grammes of iodine to the gallon.

Sample from Petersen Ranch, near Sites, Colusa County.

A sample of mother liquor, which was forwarded to the Mining Bureau from the salt works on the Petersen ranch, near Sites, in Colusa County, was found to contain 2.239 grammes of iodine to the gallon.

In each of the foregoing water analyses that portion of the residue which was soluble in water gave a slight precipitate after the addition of ammonium chloride and ammonium hydrate.

In the following table the amount of solid matter, common salt, and iodine contained in one gallon of sea water is compared with the amount held in solution by the brines mentioned in this bulletin (small fractions are eliminated):

	Solid Matter. Grammes.	Salt in 1 Gallon. Grammes.	Iodine.
Sea water maximum. (See Manual of Mineralogy, by J. D. Dana.)	139.9	Max. 93.3 Min. 69.9	
Sea water minimum. (See Manual of Mineralogy, by J. D. Dana.)	121.0	Max. 80.7 Min. 60.5	
Water from spring on Petersen ranch, near Sites, Colusa County. (Analysis made by Dr. W. D. Johnston; see Tenth Report of State Mineralogist, p. 164)	204.7	About 102.3	0.129
Well No. 3, Oil Wells Group 2, Sunset Oil District	138.8	118.1	0.075
Well No. 2, Oil Wells Group 2, Sunset Oil District	40.8	33.5	Determined qualitatively.
Spring near Flag 6, Sunset Oil District	28.3	10.6	
Well at Salt Marsh, Sunset Oil District	46.6	37.4	Determined qualitatively.
Flowing well in Sec. 13, Sunset Oil District	73.3	54.8	Determined qualitatively.
Flowing well, oil district 9 miles north of Coalinga	66.6	58.0	0.016
Mother liquor from salt works on Petersen ranch, near Sites, Colusa County			2.239

EXPERIMENTS ON EVAPORATION.

In order to get some idea as to the rate at which brine would evaporate if it were exposed to the sun and air in the Sunset Oil District, the writer conducted two experiments. The apparatus used in these experiments consisted of a thick earthenware dish eleven inches in diameter at the top, eight inches in diameter at the bottom, and two and a half inches deep. During each experiment the vessel was kept as nearly as possible about two-thirds full of brine. The record of these experiments is as follows:

Sample Marked.	Date at which Experiment Commenced.	Duration of Experiment.	Amount of Brine Taken.	Amount of Brine at End of Experiment.	Amount of Water Evaporated.
(*a*) Brine from flowing well in Sec. 15, T. 11 N., R. 24 W.	June 4, 2 P.M.	89 hours.	3,000 cc.	102 cc.	2,898 cc.
(*b*) Brine from Salt Marsh	June 24, 10 P.M.	92 hours.	3,600 cc.	470 cc.	3,130 cc.

On the day the first experiments on evaporation commenced, the following thermometric observations were made with glass Centigrade thermometers, which hung freely in the air:

Time of Observation:	$12^h 5^m$ P.M.	1^h P. M.	$2^h 30^m$ P.M.	$3^h 15^m$ P.M.	$4^h 25^m$ P.M.	$5^h 40^m$ P.M.
Thermometer exposed to sun and north wind	37.50° C.	38.50° C.	39.75° C.	40.00° C.	39.00° C.	38.75° C.
Thermometer exposed to sun but screened from north wind	42.75	42.75	45.00	44.75	40.00	39.00
Thermometer in shade exposed to north wind	36.00	37.50	37.50	37.75	37.50	37.25

The day on which these experiments were made was considered by the inhabitants of the Sunset District to be a warm, summer day. During the second experiment on evaporation the weather was somewhat cooler than during the first experiment. During the before-mentioned experiments on evaporation, the vessel containing the brine was exposed to the sun and north wind.

In this connection it is interesting to note that the maximum temperature registered by the Southern Pacific Railroad in the shade at Bakersfield on June 4, 1893, was 102° Fahr., equal to 38.5° C. An idea of the temperature prevailing in this portion of the San Joaquin Valley may be gathered from the following records of the Southern Pacific Railroad Company, of thermometric observations made in the shade at Bakersfield, during the year 1893:

Month.	Maximum.	Minimum.	Mean.
1893—January	69.0° F.	32.0° F.	45.7° F.
February	71.0	32.0	52.2
March	83.0	40.0	55.8
April	83.0	46.0	62.7
May	96.0	59.0	75.0
June	102.0	65.0	79.4
July	108.0	70.0	87.9
August	108.0	72.0	85.1
September	100.0	59.0	72.2
October	79.0	50.0	63.3
November	79.0	35.0	55.7
December	70.0	38.0	51.9

IMPROVEMENTS IN MACHINERY USED FOR DRILLING DEEP WELLS.

The following improvements have been devised and used by Mr. W. E. Youle, Superintendent of the Sunset Oil Works and of the works belonging to the Standard Oil and Asphaltum Company at Asphalto. The band-wheel and frame used in drilling deep wells is commonly held in place by jack-posts, which are keyed into heavy sills and secured by subsills and mudsills. Mr. Youle now uses a truss-frame anchored by two one-inch bolts, which extend into a sill 8 feet long and 12 inches in thickness. This sill is covered with boards and buried to the depth of about 4 feet, with earth tamped upon it. The ends of the bolts at the bottom of the sill are secured by drift keys instead of nuts. A truss-frame thus secured is found to be very stable for deep drilling, and saves about 4,000 feet of square timber. The writer saw such a truss-frame employed at the Sunset Oil District, when Well No. 3, of Oil Wells Group 2, was being drilled. The set of tools then in use weighed more than one ton, and the well was 1,300 feet in depth, but no trembling was observed in the truss-frame. The friction pulley of the sand-reel, which is used to elevate and lower the sand-pump, is usually attached to a lever which has a friction bearing on the band-wheel. It was found that this gearing had a tendency to roughen the band-wheel and injure the belt. To remedy this, Mr. Youle now sets his sand-reel at such a distance from the band-wheel that it can be run by a belt from a supplementary wheel, which is lagged on to the side of the band-wheel. This supplementary wheel is supplied with flanges to prevent the belt which drives the sand-reel from running off. This belt is put on so loosely that it can rest on carriers when the sand-reel is not in use. The carriers are placed between the pulleys, and although the belt does not sag, it is sufficiently slack to avoid, as much as possible, any friction on the sand-reel belt during the process of drilling. When the sand-pump is required, the sand-reel belt is brought into position by a tightener, which is operated by a lever. This lever is connected by a rod to an arm in the derrick, on the same principle as are the connections used when frictional gearing is employed. A back-brake is attached to the sand-reel, and it can be brought into play during the process of lowering the sand-pump by throwing it on back motion. The brake is operated by the same arm as that governing the tightener. A sand-reel was operated in this manner for three months at the Sunset Wells, without the reel and belting exhibiting any signs of being the worse for wear.

A great improvement has also been made in the bull-wheels. Those of ordinary construction consist of a wooden shaft 13 feet long and 13 inches square, with a four-winged, cast-iron gudgeon mortised on each end, around which wrought-iron bands are shrunk. Near each end of the shaft are wooden arms "put on octagon." Around the outer diameter of these arms segments or cants of planks are fastened to form the periphery of the wheel. In the wheel built by Mr. Youle, the wooden shaft is replaced by 10-inch wrought-iron drive-pipe. Two cast-iron flanges are fastened to each end of this pipe, their centers being counterbored to admit the passage of the pipe, and each end flange terminates in a gudgeon. The flanges are pressed on by hydraulic pressure, and a very rigid connection is made. The wooden wheels, which are bolted between the flanges, are simply nailed together so as to give the proper diameter to the wheels. To increase the diameter of the bull-wheel shaft an old cable is reeled upon it until it has attained the required dimensions. These wheels can be readily "knocked down" for shipment. A pair of these wheels were in constant use for five months at the Sunset Oil Wells, and showed no signs of deterioration.

In driving long strings of casing from the top, difficulty frequently arises from the pipe buckling. To obviate this Mr. Youle devised the following method for driving strings of casing from the bottom: While enough pressure is simultaneously brought to bear on the top of the casing to make it follow and to prevent the joints from pulling apart, a heavy steel coupling is screwed or riveted within the last joint of the main string of casing. The diameter of this coupling, measured between the threads, is an eighth of an inch less than the inside diameter of the casing. The constriction thus formed furnishes a shoulder for a plug, which is lowered at the end of the tools, to rest on. When the plug is in place, driving is commenced. One of the principal advantages of driving casing from the bottom is that it jars and loosens the surrounding earth or rock at the point where there is the greatest resistance to the downward passage of the pipe.

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CALIFORNIA STATE MINING BUREAU.

J. J. CRAWFORD, State Mineralogist.

BULLETIN No. 4. San Francisco, September, 1894.

CATALOGUE

OF

CALIFORNIAN FOSSILS.

(PARTS II, III, IV, AND V.)

BY

DR. J. G. COOPER.

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PREFACE.

The following pages contain papers relating to the Palæontology of California, and may be considered supplementary to the volumes on that subject published by the State Geological Survey, under Prof. J. D. Whitney, as well as to Part I of the Catalogue of Californian Fossils, published in the Seventh Annual Report of the State Mineralogist. While little attention has been devoted to this branch of science by the State Mining Bureau, as compared with more practical matters, it is thought that the contributions thus made deserve to be published. The collections were made by assistants of the Bureau, mainly by W. L. Watts, H. W. Fairbanks, and Dr. Stephen Bowers. Some interesting specimens were also contributed by Mrs. N. Barton Williams.

J. G. COOPER.

San Francisco, September, 1894.

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CATALOGUE OF CALIFORNIAN FOSSILS.

By DR. J. G. COOPER.

PART II. BIBLIOGRAPHY AND REFERENCES.

The palæontology of California differs from that of the States north of the Potomac and Ohio Rivers in the existence of more of the Neozoic formations (including Miocene, Pliocene, and Quaternary) than those of older date, showing that the elevation of this coast above the ocean was chiefly since the Mesozoic ages, and much of it took place as late as the Quaternary, or a little before the era of man.

The consequence of this late uplift is that nearly all the coast ranges and the low foothills of the Sierra are covered by strata, in some places thousands of feet thick, and often containing solid beds of fossils several feet thick, of which the greater part are identical with living species, besides others, of forms similar to those now living farther north or south, but extinct on this part of the coast.

The most interesting conclusions derivable from these facts are connected with the changes of temperature in the ocean currents, which must have occurred during the gradual elevation of the land, indicating a range from tropical to arctic, with various oscillations at intervals, each of which must have existed a long time to allow of the colonization of species from a long distance, for varying periods of time.

Other questions of much scientific interest, and perhaps leading to practical results, are connected with the study of these late fossils. Having been the subjects of investigation (in their living forms) since the time of Linnæus, about one hundred and thirty years ago, their descriptions are scattered through numerous books by European and American authors, who have often described the same species under different names, or from distant regions where some of our fossils are also found living. The identification of these descriptions is yet only partly accomplished, and the discovery of living species in a fossil state is still progressing.

Much was done in this line of study by Mr. Gabb, as published in the "Palæontology of California," but nearly as much has been discovered since. A great difficulty in the study has been the want of a complete catalogue of authors and books, with reference of each species to the first description and figure. The confused and scattered notices given by Carpenter, in the "West Coast Mollusca," were the chief sources of information on the subject at the time, and to find a grain of information required hours of search, often with negative results. The present bibliography, besides condensing the subject into system, adds very much from many sources, and is believed to be a nearly complete catalogue of the original authors and their works.

Of the authors treating only of fossils of the formations older than Miocene there are but few, and little mention has been necessary, as they are fully referred to in the "Palæontology of California." For the same reason, most of the fossils of those formations being described as new by Meek or Gabb, it is not necessary to repeat the catalogues of them given in the Report of the Mining Bureau of 1887.

As to the new species, described since that date by Dr. C. A. White in publications of the United States Geological Survey, they are also easily accessible, and do not need further cataloguing.

Some of the different groups of fossils probably indicate that they lived at different depths before the upheaval of the land, but that does not explain the facts of distribution of species now found on seashores in other regions, but extinct here.

The fresh-water deposits usually found with lignite beds in strata of various ages are of special interest, on account of their indications of the existence of dry land, as well as being proofs that the lignite is of little extent or value.

Their uplifted position also exhibits the effect of volcanic forces, and shows in arid regions what changes in climate have occurred since the period when abundant rainfall caused lakes to exist where little or no water now remains.

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For 4 others obtained by Forbes, see Carpenter, Moll. of West North Amer., p. 607 (93). (Baird, Northwest Boundary Moll.)

BINNEY, AMOS, M.D. Land Mollusca only, in Boston Journal of Nat. Hist., 1837. A monograph of the Helices inhabiting the United States, vol. I, p. 466; vol. II, pp. 353 and 405; vol. III, pp. 163 and 360. (Terrestrial Air-Breathing Mollusks of the United States, etc.), by A. Binney. Edited (after his death) by Dr. A. A. Gould, Boston, vols. I and II, 1851; vol. III (plates), 1857. Republished and continued by W. G. Binney. (Binn., Terr. Moll. of U. S.)

BINNEY, W. G. A supplement to the Terrestrial Mollusks of the United States, forming vol. IV. From the Boston Journal of Nat. Hist., vol. VII, 1859. Continues descriptions, and plates from Nos. 72 to 80, with many more West Coast species. (Suppl. Terr. Moll.)

Proceedings of Acad. of Nat. Sciences of Philadelphia (new series), 1857, p. 18, to 1876, forming three volumes.

Issued also as "Notes on American Land Shells," in combination with articles from the Annals of the Lyceum of Nat. Hist. of New York, vol. IX, 1870; vol. X, 1873. American Jour. of Conchology, vol. I to VII, 1865 to 1873.

Smithsonian Miscellaneous Collections, 1865. The latter also contain the volumes on "Land and Fresh-Water Shells of North America," in three parts, with wood-cuts. A catalogue of seventy-five of his publications (partly in connection with T. Bland) is given in vol. III of the notes from the Bulletin of the Museum of Comparative Zoölogy, Cambridge, Mass., vol. V, 1879, p. 351.

Bibliography of North American Conchology, published by the Smithsonian Institution, compiled by Mr. Binney, with catalogues of all the American species named by the authors quoted, Washington, D. C., 1863–64, 2 vols., 8vo, is very useful for books printed before 1860. (Bibl. of N. Amer. Conch.)

The Terrestrial Air-Breathing Mollusks of the United States, vol. V, being a bulletin of the Museum of Comp. Zoöl. of Harvard College, Cambridge, Mass., 1878; contains all the essential facts of previous volumes, with additions bringing it up to date, and a volume of plates, reprinted from the first four volumes; also, many others giving anatomical details from the author's later publications.

A Manual of American Land Shells, published by the United States National Museum, Bulletin No. 28, Washington, D. C., 1885, is a condensed and remodeled epitome of the subject, giving Mr. Binney's conclusions up to date. (Binney's Manual.)

A supplement to the fifth volume of Terrestrial Air-Breathing Mollusks, issued as a bulletin of the Mus. of Comp. Zoöl. at Harvard College, vol. XI, No. 8, 1883, and 4 plates, is embodied in the Manual of Amer. Land Shells, excepting some details.

A second supplement to same work from same series of bulletins, vol. XIII, No. 2, 1886.

A third supplement from vol. XIX, and No. 4, of same, 1890, contains all the information on the subject so far published. (Binney, Suppl. to Terr. Moll.)

BLAINVILLE, D. DE. Manuel de Malacologie et de Conchyliologie. 2 vols., 8vo, 190 plates. Paris, 1825–1827. (Blainv. Manuel de Mal.)

BLAINVILLE, H. DE. Annales Nouvelles du Museum, Paris, 1832, vol. I, p. 189, on living and fossil Purpuras, etc., with plates. (See Duclos.)

BLAND, THOMAS. See complete list of the scientific papers of T. Bland, F.G.S., from 1852 to 1883, by A. F. Gray, C.E., Salem, Mass., 1884. (Died August, 1885.)

BOURGUIGNAT, J. R. Proceedings Zoöl. Soc. of London, 1853, p. 81, on Fresh-Water Mollusks of United States.

Magazin de Zoölogie, Paris, 1857 to 1887; also, works on fossil shells of Europe.

BROWN, THOMAS, Captain. Recent Conchology of Great Britain. 1 vol., 4to, 62 colored plates, Edinburgh, 1827. Second edition, London, 1844.

Fossil Conchology of Great Britain. London, 1844.

BRODERIP, W. J., and SOWERBY, G. B. (Generally quoted together; the latter author preparing the plates, but sometimes each describes species separately.)

Zoölogical Journal, London, 1829, vol. IV, p. 359, descriptions. Plates of same in Zoölogy of Captain Beechey's Voyage to the Pacific and Behring's Straits, in the ship "Blossom," 1825 to 1828; published 1839, London, and with the aid of Dr. J. E. Gray. (Zoöl. of Beechey's Voy.)

Proceedings of the Zoölogical Society of London, 1832 to 1835, contain several descriptions of West Coast species by these authors. The most ornamental species have been figured by later authors quoted hereafter. (See Sowerby, Reeve, Adams, H. and A., Chenu, Tryon, etc.)

Species Conchyliorum. Monographs of various genera, 4to, 14 colored plates. London, 1830.

BRUGUIERE, M. DE. Histoire Naturelle, Mollusques, etc. Paris, tome I, 1792, 4to. Chiefly descriptions and figures of older species. Tomes II to IV finished by Deshayes in 1832.

BUCH, L. von. A writer on fossils of Germany, 1831 to 1839; also, on South American fossils.

CALL, R. E. Quaternary and Recent Mollusca of the Great Basin. From Bulletin U. S. Geol. Survey, No. 11, Washington, 1884, p. 46, plate VI, map, section, and diagrams.

Two new species and two varieties described. Twenty-two are fossils in Quaternary beds, eighteen others now living.

CARPENTER, PHILIP P. See Smithsonian Miscellaneous Collections, No. 252, Washington, D. C., 1872, for titles of his papers on American mollusca previous to that date. It contains the full supplementary report on the Mollusks of Western North America, reprinted from the report of the British Association for the Advancement of Science for 1863–64, together with twelve other papers, describing many species. (Moll. of West. N. Amer.)

Twelve papers not reprinted are to be found as follows, viz.:

Report on the present state of our knowledge with regard to the Mollusca of the West Coast of North America. From report of British Association, etc., for 1856, with 4 plates, showing variations in species of Arca, Cyrena, Gadinia, Glyphis, Fissurella, Crepidula, Crucibulum, Cœcum, Neritina. (Report to British Assoc., 1856.)

Catalogue of the Reigen Collection of Mazatlan Mollusca in the British Museum, 1855 to 1857. (Catal. of Mazat. Moll.)

Proceedings of the Zoölogical Society of London, 1855–1856, 1858–1865. Chiefly articles on West Coast shells.

Proceedings of California Academy of Sciences, III, 1864, pp. 155, 175, 207. Descriptions of new marine shells from the coast of California. (Carp., Calif. Moll.)

Journal of Acad. Nat. Sciences of Philadelphia (new series), 1865, p. 54, on New Species and Varieties of Mollusca Collected by the late Dr. Kennerly, in Puget Sound. (Carp., N. W. Bd'ry Moll.)

American Journal of Conchology, vols. I to VII, 1865 to 1873, Philadelphia. Several articles on West Coast shells.

CHEMNITZ, J. H. (Martini and Chemnitz). Conchylien Cabinet, Nurnburg, 1769 to 1795. 4to. The last date is that of vol. XI, the only one in which the binomial nomenclature is used, Martini not being an authority under Linnean rules. (Chem. Conch. Cab.)

A new edition begun in 1844 by Kuster. Monographs of all known species of each genus are given, with figures. Continued by W. Kobelt and Weinkauff to 1887. Nurnburg, 4to, 1,988 colored plates.

CHENU, J. C. Illustrations Conchyliologiques, etc. Living and fossil shells, colored plates. Paris, 1843, 79 numbers, folio. Bibliotheque Conchyliologique, a reprint of older authors and their illustrations, including works by Say, Leach, Rafinesque, Conrad, Martyn, etc.

Manuel de Conchyl. et de Palæontologie. 2 vols. grand 8vo. Paris, 1860–1862, with about 5,000 engravings, part colored. (Chenu, Manuel.)

CONRAD, TIMOTHY A. Fossil shells of the Tertiary formations of North America (Eastern). Philadelphia, 1832, 1 vol., 56 pages, 18 plates. As many West Coast fossils are very near, or identical with Eastern, they need close comparison. (Conrad's Tertiary Shells.)

Journal of Acad. Nat. Sciences of Philadelphia, vol. VII, p. 227, with 4 plates, 1837. The 45 new species described from California, with figures, form the first important article on West Coast Shells. (Conrad, Nuttall's Shells.) Some additional notes on them were given in the Journal (new series), 1849 to 1854.

American Journal of Science and Arts, New Haven, Conn., 1848. Several Oregon fossils described and figured.

Geology of the United States Exploring Expedition, under Commander Wilkes. Report vol. X, Philadelphia, 1849. Plates. Numerous Tertiary fossils described from Oregon; many of them since found in California. (Conrad, Geol. of U. S. Expl. Exped.)

Report on Explorations and Surveys for a Railroad to the Pacific Coast, vol. V, appendix 2. Fossil Shells (Miocene, Eocene), and Recent, with 9 plates, Washington, D. C., 1856. Same report, vol. VI, app., p. 69, 5 plates of Miocene and Pliocene fossils. Same, vol. VII, part 2, p. 189, with 10 plates of Miocene and Pliocene species. (Conrad, Pac. R. R. Rep't, vols. V, VI, VII.)

American Journal of Conchology, vols. I to VII, 1865 to 1873, Philadelphia. Several articles on West Coast Shells. (See "The Writings of T. A. Conrad," Bulletin U. S. Nat. Mus., No. 30, 1885.)

COOPER, WILLIAM and JAMES G. Report of Explorations and Surveys for a Railroad to the Pacific Coast. Washington, 1859, vol. XII, part 2, and separate. Also, extracted from above in "Nat. Hist. of Washington Territory," New York, 1859.

Report upon the Mollusca Collected on the Survey by William Cooper, with notes by J. G. Cooper. Species are also included from the coasts of Oregon and California, besides the land and fresh-water shells from the region north of Columbia River. (Cooper, Pac. R. R. Report.)

COOPER, J. G., M.D. Proceedings of the California Academy of Sciences, vol. II, 1862, pp. 202–207, on Nine New Californian Marine Mollusca.

Vol. III, p. 57, on New and Rare Mollusca Inhabiting the Coast of California. Eight additional species, August, 1863.

Pages 62–63, 1866, A New Genus of Terrestrial Mollusca Inhabiting California (Binneya), with wood-cuts.

Page 259, on a New Californian Helix, with notes on others.

Page 294, A New Species of Pedipes.

Vol. IV, p. 92, 1867, The West Coast Fresh-Water Univalves, No. 1 (Pulmonate).

Page 331, 1867, The West Coast Helicoid Land Shells.

Page 150, 1870, on Shells of the West Slope of North America, No. 1; p. 171, 1871, the same, No. 2.

Vol. V, 1873, The Law of Variation in the California Land Shells, with diagrams.

Pages 172, 389, 401, 419, 422, 1874, on Tertiary Geology of California, with notes on the characteristic fossils, etc.

Vol. VI, p. 12, 1875, The Origin of California Land Shells; p. 14, on Shells of the West Slope of North America, No. 3.

Geological Survey of California (J. D. Whitney, State Geologist). Geographical Catalogue of the Mollusca found west of the Rocky Mountains, between 33° and 49°, north latitude. Pamph., 4to, 40 pp., San Francisco, 1867. 795 species named. (Cooper's Geog. Cat. of Moll.)

American Journal of Conchology, Philadelphia. Vol. IV, 1868, p. 209, on a New Californian Terrestrial Mollusk, plate 18, figure 1. Page 211, on the Distribution and Localities of West Coast Helicoid Land Shells.

Vol. V, 1870, p. 196, on a New Californian Helicoid Land Shell, plate 17, fig. 8.

Page 199, Notes on West Coast Land Shells, No. 2.

Vol. VI, p. 42, 1870, Notes on Mollusca of Monterey Bay, California. 247 species. Page 319, Note on Gadinia and Rowellia. Page 320, Note on Waldheimia pulvinata. Page 321, Additions and Corrections.

Proceedings of the Academy of Natural Sciences of Philadelphia, new series, 1872, p. 143, on New Californian Pulmonata, etc. Eight species, figured on plate 3.

Proceedings of the American Philosophical Society, Philadelphia, 1879, p. 282, Notes on Some Land Shells of Pacific Coast.

Bulletin of the California Academy of Sciences, San Francisco, No. 4, January, 1886, p. 235, on Fossil and Sub-Fossil Land Shells of the United States, with notes on living species. Vol. II, No. 7, June, 1887, p. 335, West Coast Pulmonata, fossil and living. No. 8, p. 497, the same continued.

Proceedings of the California Academy of Sciences, new series, vol. I, 1887, p. 11, the same concluded. Vol. III, p. 73, 1890, The Subalpine Mollusca of the Sierra Nevada, with one plate. (Collection of W. J. Raymond.)

Seventh Annual Report of the State Mineralogist, William Irelan, to the California Legislature, 1887, Catalogue of Californian Fossils, compiled by J. G. Cooper.

Ninth Annual Report of same, 1889, Value of Fossils as Indications of Important Mineral Products.

DALL, WILLIAM HEALY. Proceedings of the California Academy of Natural Sciences, vol. III, pp. 236, 243, 258, 264, 271, 367 (1866), several papers relating to Shells and Geology of Pacific Coast. Vol. IV, pp. 182, 270, 302 (1871); two are on Mollusca, with 1 plate. Vol. V, pp. 57, 246, 296 (1873–1874), on Shells and Fossils of West Coast. See also several papers in Amer. Jour. of Conchology, 1865 to 1873.

Proceedings of U. S. National Museum, Washington, vol. I (1878–1879), pp. 1, 3, 10, 26, 281, contain articles on Living and Fossil West Coast Mollusca, with new species described and partly figured. The living species are chiefly Chitons, with 60 pages and 5 plates of dentition, etc. Vol. IV, p. 279 (1881–1882), on the Genera of Chitons; 12 pages, and analytical key. Vols. VII and VIII, 1883–1884, contain lists of papers by Dall, on West Coast and other Mollusca. Catalogue of Shell-Bearing Marine Mollusks, etc., of Southeastern Coast of the United States, in Bulletin of U. S. Nat. Mus., No. 37, Washington, 1889. Figures of a few West Coast species, mostly copies of those in Binney's Ed. of Gould's Invert. of Mass. Preliminary Report on the Collection of Mollusca, etc., obtained in 1887–1888, by the Fish Commissioners' steamer "Albatross." From Proceedings of Nat. Mus. XII, No. 773, Washington, 1889. Contains descriptions and figures of 10 new species from California coast.

Reports of the Smithsonian Institution for 1884 and later, have complete lists of Dall's articles in various publications, some of them relating to West Coast mollusca.

DAVIDSON, THOMAS. Books relating only to the Class Brachiopoda. His works date from 1850 to 1886, including both recent and fossil species. See "Index to the names which have been applied to the subdivisions of the Class Brachiopoda, previous to the year 1877," by W. H. Dall, U. S. Coast Survey, in Bulletin 8, U. S. Nat. Museum, Washington, 1877, p. 60, 8vo.

DESHAYES, G. P. (with D. de Ferussac). Histoire Naturelle Generale des Mollusques Terrestres et Fluviatiles, Paris, 1822, 1851. A few Nearctic and one Californian species described and figured.

Revue Zoölogique, Paris, 1839, contains descriptions of 14 species supposed to be new, from our West Coast, most of them figured in Magazin de Zoölogie, Paris, 1840, plates 14 to 48; also, six previously described by Conrad. Catalogue of the Conchifera in the British Museum, vol. I, 1853; vol. II, 1854. A few species from the West Coast.

Eocene Fossils of Paris. 5 vols. 4to. 1866.

DIXON, GEORGE, Captain. A Voyage Around the World. London, 1789. Appendix, p. 355, fig. 2.

D'ORBIGNY, ALCIDE (Chevalier, etc.). Voyage dans l'Amerique Meridionale, 1826–1833; Mollusca. Paris, 1874, 4to, 86 colored plates; also, published as a Catalogue of the Species in British Museum, 1854, by Dr. J. E. Gray. A few of the species reach California.

Palæontologie Française, Cretacé et Jurassique, 13 vols. Paris, 1840 to 1886. 8vo, 2,243 plates.

D'ORBIGNY, A. D. Histoire Physique, Politique et Naturelle de l'Ile de Cuba. Par M. Ramon de la Sagra; Mollusques. Paris, 1842–1853. 2 vols., 8vo, and atlas, folio. 29 plates. Also printed in Spanish.

DRAPARNAUD, J. P. R. Hist. Nat. des Mollusques Terrestres et Fluviatiles de la France. Paris, 1813. 13 plates.

DUCLOS, M. Annales des Sciences Naturelles, Paris, vol. XXIV, p. 103, with plates, 1832. Synopsis of Purpura, giving new species, etc.; also figured in Mag. de Zoöl., 1833.

DUNKER, WILHELM. Zeitschrift fur Malakozoölogie, 1874 to 1883, on Buccinum, etc., and in Chemnitz, Conch. Cab., ed. 2, on Planorbis, etc.

Novitates Conchologicæ. Series II, Cassel, 4to, 1858 to 1871, on Marine Shells only; 48 plates. (Dunker, Novit. Conch.)

ESCHSCHOLTZ, J. F. (Kotzebue's Voyages.)

Zoölogische Atlas, Berlin, 1829, completed by Dr. M. H. Rathke, in 1833; 1 vol., 4to, with 24 plates, 5 of Mollusca. About 18 species and varieties belong to the West North American Coast. (Esch. Zoöl. Atlas.)

The species are chiefly circumpolar, but a few reach California.

FISCHER, G. (de Waldheim). Oryctographie du Gouvernment de Moscou, 1809 to 1837, folio, 62 plates of fossils. (Fischer, Oryct. Moscow.)

FISCHER, P., and CROSSE, H. (See Petit, L.) Journal de Conchyliologie.

FORBES, EDWARD, Professor of Geology. Proc. Zoöl. Soc. of London, 1850, pp. 53 to 56, land shells; pp. 271 to 274, marine. West Coast species, chiefly from Lower California, collected by Captains Kellet and Wood, R.N., on a surveying voyage in ships "Herald" and "Pandora," along the West Coast. (Forbes, Kellett and Wood's Voy.)

FORBES, E., and HANLEY, S. History of British Mollusca and their Shells, London, 1855, 4 vols., 8vo, 202 plates. Many reach California.

GABB, WILLIAM M. Proceedings Acad. Nat. Sciences of Philadelphia, 1861, p. 368, on Fossils from California. Proc. Calif. Acad.

Nat. Sciences, vol. III, 1865, p. 183, New Marine Shells from the Coast of California.

Geological Survey of California (J. D. Whitney, State Geologist). Palæontology, vol. I, 1864, vol. II, 1869, with 33 plates of Jurassic, Cretaceous, and Tertiary fossils. (Gabb, Pal. of Cal.)

American Journal of Conchology, vols. I to VII, Philad., 1865 to 1873. Various articles on West Coast Shells and Fossils, with plates of new species.

GABB, W. M., and HORN, Dr. GEORGE H. Proceedings Acad. Nat. Sciences of Philad., 1862, on Living and Fossil Polyzoa from Santa Barbara, California.

GMELIN, J. F. Systema Naturæ, Leipsic, 1788, often quoted as the 13th edition of Linnæus. Vol. VI, Vermes Mollusca et Testacea, quotes species of Linnæus, Pallas, Fabricius, etc., also names of many circumpolar species that reach California. (Gmelin's Syst. Nat.)

GOULD, AUGUSTUS A., M.D. American Journal of Science and Arts, vol. XXXVIII, 1840, Notes on two Californian Shells. Proc. Bost. Soc. of Nat. History, vol. II, 1846, p. 142, on Shells collected by the U. S. Exploring Expedition under Captain Charles Wilkes, U. S. N. Continued in vol. III, p. 83, 1849–1850; IV, 27, 1851, and completed in the Official Report, 1852, Mollusca and Shells of the U. S. Expl. Exped., etc.; Boston (text), 1852, plates, 1856, issued in 1861 (Binney, Bibliography), about 50 West Coast species, mostly new. (Gould, Moll. of Expl. Exp.)

Proc. Bost. Soc. Nat. History, vol. IV, 1851, p. 87, and Boston Journal of Natural History, vol. VI, p. 374, 1853, on Shells from the Gulf of California and the Pacific Coast, with plates 14, 15, 16, and figures of 26 species found in California, by Major Rich, U. S. A., Lieutenant Green, U. S. N., and Colonel E. Jewett, during the Mexican War. (Separates called Mex. and California Shells.)

Proc. Bost. Soc. Nat. History, vol. V, pp. 126 to 128; vol. VI, 11, 1855–1856, contain descriptions of new species collected by Pacific Railroad Survey Expeditions. See P. R. R. Rept., vol. VI, p. 330, 1857, plate XI. (Gould, Pac. R. R. Rept.)

Otia Conchologica, Boston, 1862, contains descriptions of nearly all species named by Dr. Gould from 1839 to 1862, with rectifications; 188 pages, extracted from the original journal when printed, and 57 pp. reprinted, with corrections, and index of 10 pages. (Gould, Otia.)

GRAY, Dr. JOHN EDWARD. Zoölogical Journal, London, vol. I, p. 71, 1824, Monograph of the Cypræidæ; vol. III, 1827, two Californian species. Annals of Philosophy, London, vol. XII, p. 103, 1826.

The Zoölogy of the Voyage of the Ship "Blossom," Captain Beechey, London, 1839, pp. 117 to 138. Arctic and West Coast Shells; see

Broderip and Sowerby for Southern species. (Zoöl. of Beechey's Voy., Zoöl. of "Blossom.")

Proc. Zoöl. Soc. of London, 1847, p. 66, on West Coast Chitonidæ. Same, 1849, pp. 117 to 122, on Anomiadæ.

Catalogues of the Mollusca in the British Museum. Part I, Cephalopoda, London, 1849. Part II, Pteropoda, London, 1850. Part IV, Brachiopoda, 1853. See also D'Orbigny, Catal. of this collection. For catalogue of Veneridæ, etc., see Deshayes.

Guide to the Systematic Arrangement of Mollusca, part I, 1857, 8vo. (Gray's Syst. Arr. Moll.)

Figures of Molluscous Animals, by Mrs. Emma Gray (text by J. E. Gray), 418 plates, 8vo, London, 1859. (Gray, Fig. of Moll. Anim.)

HALDEMAN, S. S. Monograph of the Limniades and other Fresh-Water Univalve Shells of North America. Philadelphia, 1840 to 1844. Issued in 8 numbers, with separate paging and 35 plates. On covers are also printed descriptions of West Coast species brought by Nuttall, 1840 and 1841. The latter are figured in later numbers, 1842–4.

Same, second edition, by George W. Tryon, Philad., 1871, enlarged and corrected to date; 2 vols., many plates. (See Tryon.)

Proc. Acad. of N. S., Philad., vol. I, p. 103, 1841, on Species of Sphærium. (Hald. Mon.)

HANLEY, SYLVANUS. An Illustrated and Descriptive Catalogue of Recent Bivalve Shells, with 960 figures, by Wood and Sowerby (forming an appendix to Wood's Index Testaceologicus, ed. 3, 1856), London, 1842 to 1856; 8 plates of bivalves. The third edition of Wood's work is mostly on Univalve Shells, and 50 West Coast species are mentioned in the two volumes, chiefly the larger kinds, of which twelve or more are figured. Nearly all had been before figured by authors, and nothing is original on West Coast forms. The figures are, however, generally good. See W. Wood, Mawe, Carpenter, etc. (Hanley Bivalve Shells, or Wood's Index.)

Ipsa Linnæi Conchylia, the shells of Linné determined by his collections and manuscript. London, 6 colored plates, royal 8vo, 1855.

HAUER, T. VON. Many papers and books on living and fossil Cephalopoda (chiefly those of Austria, the Alps, etc.). Vienna, 1845 to 1866.

HINDS, RICHARD B., Surgeon, R. N. Annals of Nat. History, London, vol. X, p. 81, pl., 61 new Shells from California; and vol. XI, p. 255; vol. XII, p. 479; vol. XIII, pp. 137 and 468; vol. XIV, pp. 9 and 64, 1842 to 1844. In last three volumes, copied from Proc. Zoöl. Soc. of London, 1843 and 1844. All are republished with figures, in the Zoölogy of the Voyage of the "Sulphur," Captain Sir Edward Belcher, 1836 to 1842, Mollusca; London, 1844, with 21 plates. Over 20 new

Californian species are described and illustrated; also many Mexican. (Hinds, Zoöl. of "Sulphur.")

JAY, Dr. J. C. A Catalogue of Recent Shells in his Cabinet, with References and Synonyms. New York, 1835; edition second, 1836, and third, 1839, 4to, contain descriptions of new species and colored plates; fourth edition, 1850, 479 pp., also contains a catalogue of conchological books (Jay's Catal.). About 12,000 species are named.

Expedition to Japan under Commodore M. C. Perry, in 1852 to 1854. In vol. II, p. 289, 1856, is a list of shells, with descriptions and figures of new species by Dr. Jay. Five represent Alaskan species or varieties, and four are also found on our West Coast. See Carpenter, W. C. Moll. (Jay, Perry's Japan Exp.)

JEFFREYS, J. G. British Conchology, London, 1862–1869, 5 vols., 8vo, 147 plates. The latest and most complete general work on the subject. Many articles on special genera, etc., in various journals relate to species found in California. (Jeff. Brit. Conch.)

KEEP, JOSIAH. Common Sea Shells of California, San Francisco, 1881, 64 pp., 95 figures. (Keep's Common Shells.)

West Coast Shells, 1887, about 200 wood-cuts, much better than in Com. Shells, and include the land species. (Keep, W. C. Shells.)

KIENER, L. C. Species Generales et Iconographie des Coquilles Vivantes, 4to, Paris, 1834 to 1879; 12 volumes, containing monographs of the showy species. Continued by P. Fischer. (Kiener, Coq. Viv.)

KUSTER, H. C., Editor. Martini & Chemnitz, Conchylien Cabinet, 2d edit., begun in 1837; Nurnburg, 4to, plates. Continued by W. Kobelt and Weinkauff, Nurnburg, to 1887. (See Chemnitz.)

LAMARCK, J. B. P. de. Histoire Naturelle des Animaux sans Vertebres, Paris, vol. V, Conchifera, 1818; vols. VI and VII, Mollusca, 1822. A few circumboreal and Mexican species included, that extend to California. Second edition by G. P. Deshayes, Paris, 1835–1836, contains a few more.

Vol. VIII, 1843, quotes some Californian species from other authors. Third edition, Brussels, 1839, adds more. B. Delessert published 40 or more additional plates of Lamarck's species in Paris, 1841. (Lamarck, Hist. Nat.)

LEA, ISAAC, LL.D. A full bibliography of his numerous works on land and fresh-water mollusca, some marine shells, and many fossils of Eastern United States has been published. They began in the Transactions of the American Philosophical Society, Philadelphia, 1830, vol. IV, and were also issued as "Observations on the Genus Unio, etc.," with separate paging, but the same plates, up to vol. X. Most of the West Coast species collected by Nuttall are in vol. VI

(II) and IX (V), 1839–1844. In 1858, they were continued, in the same style, in the (4to) Journal of the Acad. of Nat. Sciences of Philadelphia, vol. III. Diagnoses of new species were usually first published in the "Proceedings." (Lea, Observ.)

LEACH, DR. WILLIAM E. The Zoölogical Miscellany, 3 vols., 150 plates, 1814–1817. The conchological parts also translated into French by Chenu, in Bibl. Conch. (Leach, Zoöl. Misc.)

LINNÉ or LINNÆUS, CARL (Author's Editions). Systema Naturæ, 10th edition, Halle et Magdeburg, 1760. Vol. I. A few of his Arctic and Pelagic species reach the North Pacific.

See Hanley's Ipsa Linnæi Conchylia, the Shells of Linnæus, determined from his manuscript and collections, with an exact reprint. London, 1855. Species described by Gmelin and other authors of later editions are often credited to Linnæus, whose latest authorized edition is the 12th, 1766–1768. (Linn., Syst. Nat.)

MARCOU, JULES. See "The Writings of Jules Marcou," in Bulletin of U. S. Nat. Mus., No. 30, by J. B. Marcou, Washington, 1885, on Mesozoic and Tertiary Geology of America, with some plates of fossil shells.

MARTYN, THOMAS. The Universal Conchologist. London, 1784, 1 vol., 4to, 77 colored figures. Ten species from California and northward were first described and figured in this work, according to Carpenter, but some were assigned to New Zealand, and others had names preoccupied. The figures are said to be very fine, and were reproduced by Chemnitz.

A reprint is in Chenu's Bibliotheque Conchyliologique, Paris, 1846. (Martyn, Univ. Conch.)

MAWE, J. (See Wood's Index Testaceologicus.) The Linnæan System of Conchology, 3d ed., with additions by Mawe, and 7 colored plates. London, 1825. Most of his West Mexican species are credited to Wood, a prior author.

MEEK, FIELDING B. Geological Survey of California, by J. D. Whitney. Palæontology, vol. I, Carboniferous and Jurassic Fossils, by F. B. Meek, 1869. 6 plates. See "The Published Writings of F. B. Meek," in Bulletin No. 30, U. S. Nat. Museum, compiled by J. B. Marcou, Washington, 1885.

MENKE, C. T. Synopsis Methodica Molluscorum, Pyrmont, 1830, 2d ed.——Zeitschrift fur Malacozoölogie, 1844–1853.

MIDDENDORF, A. TH. VON. Memoirs des Sciences Naturelles de l'Academie Imperiale des Sciences, St. Petersburg, 1847–1849. Also, separate as Beiträge zu Einer Malacozoölogie Rossica, part I, 1847; parts II, III, 1849. Also, in "Reise in Sibiriens," vol. II, 1851. A

very full synopsis of the Shells of the Arctic regions of both continents as then known, with many supposed Alaskan species reported as being from South America and elsewhere. See Carpenter's Moll. of Western North America, p. 533. (Midd., Beitrage.)

MÖLLER, H. P. C. Index Molluscorum Grœnlandiæ, Copenhagen, 1842. New species described. A few of the species reach California. (Möller, Moll. Grœnl.)

MONTAGU, G. Testacea Britannica, or Natural History of British Shells, London, 1803, 2 vols., 4to, 16 colored plates. Several of the species are found on the West Coast of America.

Account of New or Rare British Shells, London, 1815, 4to, 3 plates.

MORCH, O. A. L. Malakozoölogische Blätter, vol. VI, 1859, etc. Proceedings Zoöl. Soc. of London, 1861, pp. 145–181, Review of the Fam. Vermetidæ; 2d part, p. 326; 3d part, 1862, p. 54. Novitates Conchologicæ, Series II, 1858–1870, Sitka Shells, by Morch & Dunker.

MORSE, E. L. Proceedings of Boston Soc. of Natural History, vol. VI, p. 128; vol. VIII, p. 28, 1857–1859. See W. G. Binney's Manual of American Land Shells for further references.

MÜLLER, O. F. Vermium Terrestrium et Fluviatilium Historia, Copenhagen, 1773–1774, 2 vols., folio, with colored plates. Circumboreal Shells.

Zoölogia Danica, 4 vols., folio, Copenhagen, 1788–1806, 160 colored plates. (Müll. Zoöl. Dan.)

NEWCOMB, WESLEY, M.D. Annals of the Lyceum of Natural History of New York, vol. VII, 1860, p. 146; and 1861, p. 287, on New Pupillæ.

Proceedings California Acad. Nat. Sciences, 1862, vol. II, p. 91, on New California Pulmonata; 1863, vol. III, pp. 115, 121, on Land and Marine Mollusca.

NUTTALL, THOMAS, Professor Natural Sciences, Harvard University. The collections already mentioned as described by Conrad and Lea, from the Pacific Coast in 1837 and 1839, were collected by Nuttall in 1834 and 1835. He gave manuscript names to many of his species, which were distributed as labeled, but not described, and some of them appear thus in Jay's catalogues, but are only synonyms, chiefly of the species described by Middendorff, as well as by later authors. A few were named by Reeve from Nuttall's labels. (See Reeve.)

Carpenter did the same for species of Nuttall described in Proc. Zoöl. Soc., 1856, and apparently Phillipi, also. See "The Mollusca of Western North America," pp. 636 to 663; also, descriptions reprinted from Jour. de Conch. in Appendix.

PETIT, L. (de la Saussaye.) Journal de Conchyliologie, Paris, 1850–1853 (first series), including both recent and fossil shells (colored plates). Continued by P. Fischer, A. C. Bernardi, and H. Crosse.

PFEIFFER, C. and L. On Land and Fresh-Water Mollusca only; numerous publications between 1821 and 1870. As the references to United States species are all quoted by W. G. Binney, in the Manual of American Land Shells, and elsewhere in works easily accessible, it is unnecessary to quote all original publications here. (Novitates Conchologicæ. See Dunker.)

PHILLIPI, R. A. and E. B. Abbildungen und Beschreibungen Conchylien, etc., Cassel, 1842 to 1851. Published in parts, with 144 plates, 3 vols., 4to. (Phil. Abbild.)

In Kuster's edition of Martini and Chemnitz's Conchylien, 1844 and later, monographs of various genera. Also in German and English scientific journals, 1845 to 1853. Most of his Western United States species (according to Carpenter), as well as the Mexican, had been before described.

PRIME, TEMPLE. Monograph of American Corbiculadæ, Recent and Fossil, with wood-cuts of all living species. Washington, D. C., 1865. Smithsonian Miscellaneous Collections. References given to all prior descriptions. (Prime, Mon. Corbic.)

American Journal of Conchology, vol. VI, 1869, Catalogue of the Corbiculadæ. Report of the U. S. Geog. Surveys west of longitude 100°, under Captain G. M. Wheeler, Washington, 1875, Vol. V, p. 949, Mollusca, by Dr. H. C. Yarrow. Note by Prime. (Latest publication, 1878.)

QUENSTEDT, F. A. Petrefactenkunde Deutschlands, Tubigen, 1849, 8vo; atlas, 36 plates, folio. (Quenst. Petrifact.) Die Fossilen Brachiopoden, Leipsic, 1871, 8vo; atlas, 25 plates, folio. (Quenst. Foss. Brach.) Die Ammoniten des Schwabiens Juras, Stuttgart, 1883–1887, 8vo; atlas, 78 plates, folio. (Quenst. Ammonit.)

RECLUZ, M. C. (see Petit). Journal de Conchyliologie, Paris, 1853 to 1872, first series. See Index Generale et Systematique des Vingt Premiers Volumes, etc., Paris, 1878. The Journal is still issued, by Crosse and Fischer. (Recluz, Jour. de Conchyl.)

REDFIELD, JOHN H. Annals of New York Lyceum of Nat. Hist., vol. IV, p. 163, and later articles on Marginella.

REEVE, LOVELL A. (and G. B. Sowerby). Proc. Zoöl. Soc. of London, 1842–1846 (repeated in Annals of Nat. Hist.) A few West Coast Shells.

Conchologia Iconica, 4to, London, 1843 to 1878. Illustrations of Shells, classified, with monographs by various authors. The figures are very fine, but errors occur in the text, many of which are corrected by Carpenter in Moll. of Western North America, p. 562. Over 2,700 plates have been issued. Continued since 1865, by Sowerby. (Reeve, Conch. Icon.)

REMOND, AUGUSTE. Proceedings of the Cal. Acad. of Nat. Sciences, vol. III, 13–52, 1863, on New Tertiary Fossils (two Mollusks, five Radiata). See also his Geological Explorations in Northern Mexico, on p. 244 of same volume, March, 1886. See also Palæontology of California, vol. II, p. 270, and figures of his new species, by W. M. Gabb.

ROEMER, Dr. FERDINAND. Texas, Mit Einem Naturwissenschaftlichen Anhange, Bonn, 1849. Catalogues of Mollusca and Fossils given, but none of his new living species extend to California. (Roemer, Kreidebild.)

ROWELL, Rev. JOSEPH. (See Newcomb.) Proceedings California Acad. Nat. Sciences, vol. III, p. 21; 1863, p. 353. Mr. Rowell also collected largely at Panama, etc. See Carpenter's Moll. of Western North America.

SARS, M. and G. O. Works on Mollusca of Norway, issued from 1835 to 1838, 8 vols., and many plates. Bergen and Christiania. Some Arctic species also found in California.

SAY, THOMAS. (Reprint of works by Binney.) The complete writings of Thomas Say, on the Conchology of the United States, edited by W. G. Binney, New York, 1856 to 1858, with 75 plates, mostly from originals on copper; a few fac similes of lithographs. 1 vol., 250 pp. The species extending to the West Coast are all small land and fluviatile mollusks. One or two by older authors are figured that may be identical on both shores of North America. The fossils especially need close comparison. His writings date from 1817 to 1834, he being the first American conchological author.

SHUMARD, B. F. See writings of B. F. Shumard in Bulletin of U. S. Nat. Mus., No. 30, Washington, D. C., 1885.

SOWERBY, JAMES, and JAMES De CARLE. The Mineral Conchology of Great Britain, 12 vols., 8vo, 648 colored plates, London, 1812–1829. (Sby. Min. Conch.)

The Genera of Recent and Fossil Shells, London, 1820–1824, 2 vols., 8vo, and Zoölogical Journal, 1825–1835, 5 vols., 8vo, both with colored plates, illustrate several West U. S. Coast species of other authors, as well as their own new ones. (Sowerby, Genera.)

SOWERBY, GEORGE B. (See Broderip.) A Catalogue of the Shells in the Collection of the Earl of Tankerville, with an Appendix, describing new species. Small 4to. 9 plates, colored. London, 1825.

Ten or more Californian species are named, and some described. See Carpenter's Moll. of West Amer., p. 522, showing enormous prices set on some common Californian shells, then rare. (Sby. Tank. Catal.)

The Malacological Magazine. Part II. London, 1838–1839. Monograph of Genus Margarita (figured in next work).

SOWERBY, G. B. and G. B., JR. The Conchological Illustrations, colored figures of all hitherto unfigured recent shells. London, 1832–1841, 2 vols., 12mo, 200 plates. Several Californian and Mexican species (chiefly described by other authors) are figured. (Sby. Conch. Ill.)

A Conchological Manual, illustrated by 500 figures of shells. London, 1839. (Sby. Conch. Manual.)

Thesaurus Conchyliorum, or Figures and Descriptions of Shells. Published in parts, 1842 to 1859. Excellent illustrations of all the new species obtained, with monographs of many genera by A. Adams, Hanley, Hinds, etc. See also Reeve, Conchologia Iconica. (Sby. Thes. Conch.)

STEARNS, ROBERT E. C. Proc. Cal. Acad. Nat. Sciences, vol. III, pp. 275 to 384. Several Catalogues of West Coast Shells, and notes on habits, etc. Vol. IV, p. 226, 1872, various papers on distribution of shells. Vol. V, 1873–1874, pp. 77 and 78, New Marine Mollusks from the West Coast of North America. Several papers on other subjects. Later papers and descriptions of New Mollusca from the West Coast will be found in current Eastern journals. Several new species were described in loose sheets issued as "Conchological Memoranda."

STIMPSON, WILLIAM. Proc. Bost. Soc. of Nat. History, vol. III, 1850, vol. IV, 1851–1852, contain descriptions of many Eastern Marine Mollusks, with some also found in the North Pacific.

Proc. Acad. Nat. Sciences of Philad., 1855, p. 375. Descriptions of some of the New Marine Invertebrates from Chinese and Japanese Seas, etc., all being species without external shells, need comparison with those of Western North America. Also, papers in the American Journal of Conchology, 7 vols., 8vo, 1865–1872.

SWAINSON, WILLIAM. Zoölogical Illustrations, including Figures and Descriptions of Birds, Insects, and Shells, 6 vols., 8vo, 318 colored plates. The Shells in 5 parts, 40 colored plates, 4to, London, 1820 to 1833. (Sw. Zoöl. Ill.)

Exotic Conchology, or Drawings of Rare Shells, etc., 48 plates, 4to, London, 1834. Also, 2d ed. by Hanley, 1841. (Sw. Exot. Conch.)

TRASK, J. B. (first State Geologist of California). Proc. Cal. Acad. Nat. Sciences, vol. I, 1855, pp. 27–29, Descriptions of New Species of Naiades. p. 39, Description of Ammonites Batesii. p. 40, Description of Fossil Shells. p. 85, New Species of Ammonite and Baculite. p. 93, Descriptions of New Species of Plagiostoma.

TRYON, GEORGE W. A Monograph of the Order of Pholadacea, etc., 1 vol., 8vo, 1 plate, Philadelphia, 1862.

Editor of the American Journal of Conchology, Philadelphia, 1865–1872, 7 vols., 8vo. Numerous plates.

Monograph of the Fresh-Water Univalve Mollusca of the United States, a new edition of Haldeman's work, with many additions, 2 vols., 8vo, with colored plates. Philadelphia, 1871. (Tryon's Ed. Hald. Monog.)

American Marine Conchology, Philadelphia, 1873–1874 (Atlantic Coast only), 1 vol., 8vo, 208 pp., 44 plates. (Tryon's Marine Conch.)

Manual of Conchology, Structural and Systematic. Philadelphia, 1879 to 1888, 11 vols. (five on Land Shells). This most complete and perfect general work on Mollusca, with figures of all known species, finely colored by hand, is being continued by Mr. H. A. Pilsbry. (Tryon's Manual.)

VALENCIENNES, A. Recueil d'Observations de Zoölogie, etc., par Al. de Humboldt et A. Bonpland. Vol. II. Paris, 1833.

Voyage autour du Monde sur la "Venus" pendant les Anneés 1836–1839, par M. du Petit Thouars. 24 plates; issued in 1846. (Val. Voy. "Venus.")

WHITE, C. A. On Invert. Foss. from Pacific Coast, from Bull. of U. S. Geol. Survey, No. 51, Wash., 1889. Contains descriptions and figures of seventeen Cretaceous and two Eocene species from California, with plates; also several others from Oregon and Washington, with older Mesozoic species from Alaska. See Catalogue of the published writings of Dr. White, on Fossils, 1860 to 1885, by J. B. Marcou, in Bulletin of U. S. Nat. Mus., No. 30, pp. 103 to 181.

WOOD, SEARLES V. Monograph of the Crag Mollusca. 5 parts. London, 1886–1887, 4to, 81 plates.

Eocene Bivalves, 1 vol., 1860 to 1877, 4to, 28 plates. (Wood, S., Crag Moll. and Eocene Biv.)

WOOD, WILLIAM. General Conchology, royal 8vo, 59 colored plates. London, 1859. Index Testaceologicus; Catalogue of Shells according to the Linnæan System, 8vo, 2,300 colored figures; same date. See also Hanley's third edition, 1856. (Wood's Index Test.)

WOODWARD, S. P. A Manual of the Mollusca; Recent and Fossil Shells, London, 1851, 1 vol., 12mo, 25 plates, and many wood-cuts. Also a later edition by R. Tate, with additions. Contains figures of some West American shells. (Woodw. Man.)

PART III.

ADDITIONS TO THE CATALOGUE OF CALIFORNIAN FOSSILS OBTAINED SINCE 1888.

TERTIARY AND QUATERNARY MOLLUSCA.

A supplementary list is here given of the additions made to the described species of fossils found in the State since 1888. Many others are still undetermined. It has been possible to identify several of the species described by Conrad, which were marked in the Catalogue of 1888 as "not identified," fresh specimens of them having been obtained by Dr. Bowers near the original localities. These are named in the following list, but in some cases will probably be found to be synonymous with species before named:

1. *Arcopagia unda* Conr.
2. *Dosinia longula* Conr.
3. *Ostrea panzana* Conr.
4. *Ostrea subjecta* Conr.
5. *Pecten deserti* Conr.
6. *Pecten discus* Con.
7. *Pleurotoma transmontana* Conr.
8. *Purpura petrosa* Conr.
9. *Saxicava abrupta* Conr.
10. *Venus pajaroensis* Conr.

Of these, numbers 1, 2, 3, 4, 6, 7 may prove good species, but the specimens are scarcely good enough to decide as yet. Nos. 8, 9, 10 are probably the species suggested in the Catalogue of 1888.

In quoting original descriptions and figures the full synonymy is not given, but merely the first author, and one or more later or easily found descriptions or figures, when any such is known.

Of Cretaceous and Eocene fossils many additional localities have been found, and the list of species occurring in the Santa Ana Mountains of Orange County was much increased by the collections of Dr. Bowers. Several more species have thus been added to the list of those also found in Northern Mexico, Texas, and more eastern states, showing a connection of the oceans before the Tertiary age.

ADDITIONS TO TERTIARY AND QUATERNARY FOSSILS.

Acmæa? instabilis Gould.

U. S. Expl. Exp'd., Moll., p. 9.
Living—Straits of Fuca to Monterey.
Quat.—San Nicolas I. (Bowers).

Amiantis callosa Conrad.

Jour. Acad. Nat. Sc. Phil., vol. VII, 1837, p. 252.——Keep, Common Sea Shells, 1881, pl. 14, f. 5.
Living—Santa Barbara to Cape St. Lucas.
Quat.—Orange County (Bowers).

Arca ponderosa Say?

Jour. Acad. Nat. Sc. Phil., vol. II, p. 267, 1822.
Living—Southern U. S. Coast.
Pl.—Same coast (and West Coast?).

Calliostoma supragranosum Carpenter.

Moll. of W. North Amer. (1864), p. 139, 653.——Carpenter, Proc. Cal. Acad. Sc., vol. III, p. 214, 1865.
Living—Monterey to San Pedro? San Diego.
Pl.?—Ventura County (Bowers).

Pterorhytis foliatus Martyn.

Univ. Conchol., No. 66, pl. 24, f. 1, 1784.——Keep, Common Shells, p. 21, pl. 3, f. 6.
Living—Sitka to Santa Barbara. Asia.
Quat.—San Joaquin Bay, Orange County (Bowers).

Chama exogyra Conrad.

Jour. Acad. Nat. Sciences, Philad., 1837, p. 256.
Living—Bodega Bay to San Diego. Mazatlan?
Quat.—Santa Barbara to San Pedro. San Nicolas Island (S. Bowers).

Chama pellucida Sowerby.

C. spinosa Broderip, var. 2. Proc. Zoöl. Soc. Lond., 1834, p. 150.——Carp., Moll. of W. N. America, p. 641 (127).——Keep, West Coast Shells, p. 182, f. 155.

These two forms seem to intergrade, and are often hard to separate, especially the fossil specimens.

The former also runs into *C. exogyra* Con., which sometimes has dextral and sinistral shells together in one group. Whether any of them are identical with the tropical species of same names or not is still uncertain, or the two former may be dwarfed varieties of other species.

Living—*C.* "*pellucida,*" Farallon Islands to San Diego. South America. *C.* "*spinosa,*" Catalina I. to San Diego. Mexico. Galapagos Is.?

Pl.—Ventura County (S. Bowers).

Chama spinosa Broderip.

Proc. Zoöl. Soc. Lond., 1834, p. 150.——Reeve, Conch. Icon., pl. 7, f. 35.

Living—Catalina I. to San Diego. Mexico.

Mioc.?—Ventura County (Bowers).

Chrysodomus spitzbergensis Reeve.

Fusus spitzbergensis Reeve. Last of the Arctic Voyages (Belcher's), 1855, vol. II, p. 359, pl. 32, f. 6, a, b.——W. Cooper, Pac. R. R. Report, vol. XII, p. 370.

Living—Spitzbergen I., Arctic Sea. Norton Sound, Alaska (Murdock).

Quat.—Santa Barbara (S. Bowers). A very small specimen, identified by Mr. Dall. (Comp. *Siphonalia fuscotincta* Carp.)

Conus brunneus Wood.

Index Testac. Suppl., 1828, pl. 3, f. 1.

Living—Cape St. Lucas and West Mexico.

Mioc.—Simi, Ventura County (S. Bowers).

Cyathodonta undulata Conrad.

Proc. Acad. Nat. Sc. Phil., 1854, p. 121.

Living—Santa Barbara to Gulf of California.

Pl.—Ventura (S. Bowers).

Cylichna inculta Gould.

Pac. R. R. Rept., vol. V, app. p. 330, pl. XI, f. 27, 28, 29.

Living—San Diego.

Quat.—Ventura County (Bowers).

Cypricardia pedroana Conrad.

Petricola pedroana Con. Pac. R. R. Rept., vol. V, app. p. 324, pl. III, f. 24. Identified by Dall from type.

Quat.—"Recent Formation, San Pedro" (W. P. Blake). Los Angeles City, about 20–30 feet below surface (Mrs. M. B. Williamson). Large colonies of this fossil were found in making excavations into the terraces north of the city.

From their fragile condition it was impossible to preserve entire specimens, though the shells were from one eighth to one sixth inch thick, long soaking by rain water having softened them.

All differ from "*P. pedroana*" as figured, in the absence of concentric ridges and radiating lines. Although called "recent" by Blake and Conrad, this is certainly an extinct species, and from those associated with it seems Pliocene, or at least Quaternary.

Fusus ambustus Gould.

Proc. Bost. Soc. Nat. Hist., 1851, in part, Mexican and Californian Shells, p. 12, pl. 14, f. 18.

Living—Southern California? Mazatlan.

Pl.—Dead Man's Island, San Pedro Bay (Mrs. Williamson). Ventura County (Bowers).

Fusus corpulentus Conrad.

U. S. Expl. Exp., Geology, p. 728, pl. 20, f. 4.——Amer. Jour. of Conch., 1865, p. 150.——Dall, Proc. U. S. Nat. Mus., vol. XIV, 1891, p. 179.

Mioç.—Astoria, Oregon. Dead Man's Island, San Pedro Bay, Cal. (Miss Monks and Mrs. M. B. Williamson).

Plioc.?—Mr. Dall calls this island Miocene, but the proportions of living species found there do not indicate older strata than Pliocene. The upper layers seem to be Quaternary.

Mr. Gabb also considered the lower beds Miocene, but many more species have been collected since he was there.

Fusus dupetithouarsi Kiener.

Coq. Vivants, No. 11, p. 15, pl. 11 (date?).

Living—Cape St. Lucas and West Mexico.

Quat.—Santa Barbara to Dead Man's I., San Pedro Bay (S. Bowers). Specimens obtained by Whitney's Geological Survey were referred to this species, but were too imperfect for certainty. Dr. Bowers' better ones, compared with recent Mexican shells, show no difference.

Gadinia reticulata Sowerby? (var. *radiata*, J. G. Cooper).

Proc. Zoöl. Soc. of Lond., 1835, p. 6, Mouretia.——Carp., Shells of West N. America, p. 152, 651.——Gabb., Proc. Cal. Acad. Sc. 3, p. 188. (*Rowellia radiata* J. G. Cooper.) Dall, Amer. Jour. Conch., VII, 1870, pl. 2 and 4.——Keep, West Coast Shells, p. 98, f. 83.

Living—Farallon I. to San Diego. Mexico.

Quat.—San Nicolas I. (S. Bowers.)

Glyphis densiclathrata Reeve.

Conch. Icon., *Fissurella*, pl. 9, sp. 64.
Living—Ballenas Bay to San Diego.
Quat.—San Joaquin Bay, Orange County (Bowers).

Lottia gigantea Gray.

Philos. Trans., 1833, p. 800.——Sby. Gen., pt. 42, fig. 1.——Reeve, Conch. Syst., II, f. 1.——Carp., Jour. de Conchyl., XII, 1865, p. 140.——Moll. of West N. Amer., p. 309.——Dall, Amer. Jour. of Conch., VI, 1871, pp. 238, 290.——Keep, Common Shells, p. 40, pl. XI, f. 1.——West Coast Shells, p. 98, f. 84.
Living—Farallon Is. to Lower California. South America?
Pl.?—Santa Rosa I. (C. D. Voy).
Quat.—San Nicolas I. (S. Bowers).

Lucapina crenulata Sowerby.

Tank. Catal., 1825, VI, No. 796. Conch. Ill., No. 19, f. 31, 38.——Keep, West Coast Shells, p. 95, f. 79.
Living—Monterey to San Diego.
Quat.—San Joaquin Bay, Orange County, and Ventura (S. Bowers).

Macron kelleti A. Adams.

Pseudoliva kelleti, Proc. Zoöl. Soc. Lond., 1853, p. 185.——Carpenter, Moll. of West Amer., 1863, p. 664 (150).
Living—Catalina I. to Lower California.
Quat.—San Joaquin Bay, Orange County.
Pl.—Ventura (S. Bowers).

Mangilia angulata Carpenter.

Ann. and Mag. Nat. Hist., 1865, p. 182.——Moll. of West N. Amer., p. 284.
Living—Straits of Fuca to San Diego.
Quat.—San Joaquin Bay, Orange County (Bowers).

Mangilia hexagona Gabb.

Proc. Cal. Acad. Sc., III, 1865, p. 185.
Living—Monterey to Catalina Island.
Quat.—Sta. Barbara (S. Bowers).

Margarita cidaris Carpenter.

Ann. and Mag. Nat. Hist., XIV., 1864, p. 426.——XV, 1865, p. 29. Moll. of West N. Amer., p. 238.——*Solariella oxybasis* Dall, Proc. Nat. Mus., 1889, p. 352, pl. XII, f. 6, young.
Living—Neeah Bay, Wash. (J. G. Swan).

Quat.—Dead Man's Island, San Pedro Bay (Mrs. M. B. Williamson). Carpenter describes this shell, but gives it as named by A. Adams. No reference to Adams' works is given. Identified by Mr. Dall, from types.

Note.—The locality for the fossil shell quoted in the Catalogue of Fossils, 1888, "San Marcial." cannot be found in California. Such a place is on the peninsula, east side, near latitude 25° 30′, where fossils were collected by Aug. Remond, and is in the belt of Tertiary according to Gabb.

Modiola modiolus Linné.

Syst. Nat., No. 1158.——Binney, Gould's Moll. of Mass., p. 186, f. 485.

Living—Circumboreal, south to San Pedro in Calif.

Mioc.—Ventura County (S. Bowers).

Monoceros lapilloides Conrad.

Jour. Acad. Nat. Sc. Phil., VII, 1837, p. 265, pl. 20, f. 18.——Keep, Common Shells, p. 19, pl. III, f. 1.

Living—Monterey to Santa Barbara.

Quat.—Ventura County (Bowers).

Murex radix Gmelin (var. *nigritus*, Phillipi).

Syst. Nat., p. 3527, No. 10.——Reeve, Con. Icon. Murex, pl. 17, f. 69, 1845.——Phil., Abbild., 1845, p. 1, pl. 1.——Carp., Mazat. Shells, p. 521, 525 (*M. princeps* Brod., 1832).

The Rev. J. Rowell compared the specimens with a large series of the above forms from west tropical America, and considers them between *nigritus* and *princeps*. They doubtless represent an ancestral form, now more or less divided into sub-species. *M. radix* was also found fossil by H. Hemphill, in Southern or Lower California. (Catal. of N. Amer. Shells, 1890.)

Living—Margarita Bay, Lower California, to Panama (and South America?).

Mioc.—Foothills of Orange County at over 1,000 feet elevation (S. Bowers).

Murex trialatus Sowerby? (not of Kiener or of other authors).

The synonymy is very unsettled. Not found in tropical America?

Living—San Diego and southward. Determined by Mr. Dall.

Pl.—Ventura (S. Bowers). Except in absence of a spur, smaller mouth, and various color-bands, this shell does not differ much from *Pterorhytis foliatus*, and may be only a southern variety of that variable shell.

Muricidea subangulata Stearns.

Proc. Cal. Acad. Sciences, vol. V, p. 81, pl. 1, f. 4, 1873.

Living—San Miguel Island, Santa Barbara County (W. G. W. Harford).

Quat.—San Nicolas Island, Ventura County (S. Bowers).

Mya arenaria Linné.

Syst. Nat., p. 1112.——Dall, Shells of S.E. Coast of U. S., 3 figures.

Living—Circumboreal; south to England, South Carolina, Sitka, Japan. Naturalized in San Francisco Bay.

Pl.—San Joaquin Valley. Not on coast nor in Quaternary beds. Specimens of this familiar species have long been suspected to occur in the valley, but only in 1893 was their identity established by many perfect specimens brought by Mr. Watts from west of Tulare Lake. Their absence from the Quaternary along the coast, and the cause of their extinction at present between San Joaquin Valley and Sitka, while they have increased enormously in San Francisco Bay since reintroduction in 1869, are problems which deserve thorough investigation. Not the slightest specific difference exists between these fossils and recent specimens from San Francisco Bay, Eastern U. S., and England.

Nassa californiana Conrad.

Schizopyga californiana Con. Proc. Acad. Nat. Sc. Phil., 1850, p. 315–; Pacif. R. R. Rep., VI, p. 69, pl. 2, f. 1, 1857.——Dall, Proc. U. S. Nat. Mus., 1891, p. 177 (Nassa). *N. fossata* var., Gabb, Pal. of Cal., vol. II, p. 47, 74, 1869, and of authors.

Living—Drake's Bay to Cedros Is., Lower Calif., in 25–65 fms. U. S. Fish Comm. (Dall).

Pl.?—Dead Man's I., San Pedro, and Los Angeles City (Miss Monks, Mrs. Williamson, etc.).

Mioc.—Sta. Clara County, and other localities. Mr. Dall separates this from *N. fossata* as the "ancestor," although it is also found living, and is more probably a deep-water form connected by intergrades. They were combined as *N. fossata* in Pal. of Cal., vol. II.

Natica russa Gould.

Proc. Bost. Soc. Nat. Hist., 1859, Expedition Shells.——Otia, p. 109, 1862.——Carp., Moll. of West Amer., 1863, p. 586 (72).

Living—Arctic Ocean, Pacific side (Stimpson).

Quat.—Sta. Barbara (S. Bowers). Separated by Dall from *N. clausa*, as given by Gabb in Pal. of Calif., p. 77.

Ocinebra circumtexta Stearns.

"Occasional papers," May, 1871.——Amer. Jour. of Conch., March, 1872, vol. VII, p. 172, pl. 14, f. 14 (not 15).——*O. lurida*, var. d. Carp., Mss.——No. 762 (J. G. Cooper), Geog. Catal., part.——Keep, West Coast Shells, p. 24, f. 6.

Living—Monterey to San Miguel I.

Quat.—San Joaquin Bay, Orange County, and San Nicolas Island (S. Bowers).

Ocinebra poulsoni Carpenter.

Jour. de Conchyl., XII., 1865, p. 148.——Moll. of West. Amer., p. 151, 316.

Living—Santa Barbara to San Diego.

Quat.—Ventura, Calif. (S. Bowers).

Ostrea palmula Carpenter.

O. conchaphila, var. *palmula*. Carp., Mazatlan Shells, p. 163, 1857; "A distinct species," in Appendix, p. 550. Also, in Proc. Zoöl. Soc. Lond., 1863, p. 364.——Moll. of West. Amer., pp. 199, (646), (132).

Living—San Diego to Panama.

Pl.—Ventura County (S. Bowers). Identified by Dall. This is one of the marine plicated forms like *O. vespertina* Conrad, and several others of my former Catalogue, that will probably be united as one species.

Ostrea subfalcata? Conrad.

Foss. of Med. Tertiary Formation, p. 50, pl. XXV, f. 2.——Heilprin, in Foss. Ost. of N. Amer. Geol. Rept., 1884, p. 313, pl. 68, f. 1, 2, 3.——C. R. Orcutt, "The Colorado Desert," in 10th Annual Report of the State Mineralogist, 1890, pp. 839–916.

Carrizo Creek, San Diego County (C. R. Orcutt). The "expert" of the U. S. Geol. Survey, who named the specimens sent from Carrizo Creek by Orcutt, may have easily mistaken those of *O. vespertina* Con. for the above-named fossil, before known only from Virginia, though there are some strong differences in the types as described by Conrad, who also remarks on their resemblances. It might be supposed that if *O. virginica* can have existed on this coast, any other Eastern species could also. This is quite possible, and some of those described by Carpenter as now living on the west Mexican coast may prove to be the connecting links. The species called *O. veatchii* by Mr. Orcutt is probably *O. heermanni* Con., the former not having been before recognized at Carrizo Creek. Still they may be identical species.

Ostrea virginica Gmelin.

Syst. Nat., p. 3336, No. 113.——Binney, Gould's Moll. of Mass., p. 202.——White, Foss. Oysters, in 4th Report of U. S. Geol. Survey, 1884, p. 284, 314, pl. 77 to 81.——Carp., Moll. West. Amer., p. 306.

Living—Gulf of St. Lawrence to Central America. Panama (C. B. Adams, ident. by Carpenter). Margarita Bay and Cape St. Lucas, Lower Cal., Mazatlan, Honduras, Guayaquil, S. A. (Also, China and Australia?)

Pl. and *Mioc.*—N. Jersey to Florida (White).

Pecten expansus Dall.

Proc. U. S. Nat. Mus., vol. I, p. 14, 1878.

Pl.—San Diego (omitted in Catal., 1888).——One of the links between the *Miocene P.* (*Amusium*) *propatulus* Con., and the *Living* (*P. caurinus* Gould).

Pecten floridus Hinds.

Zoöl. Sulphur, p. 246, pl. 17, f. 6.

Living—Monterey to San Diego.

Quat.—Ventura and Springville, California (S. Bowers).

Ranella californica Hinds.

Ann. Nat. Hist., XI, p. 255, 1843.——Zoöl. Sulphur, p. 12, pl. 2, f. 4, 5.——Keep, West Coast Shells, p. 44, f. 24.

Living—Monterey to San Diego.

Quat.—Dead Man's Island, San Pedro (S. Bowers).

Scala hindsi Carpenter.

Proc. Zoöl. Soc. Lond., 1856, p. 165.——Moll. of West. Amer., p. 146 (660).——*S. subcoronata*, Keep, West Coast Shells, p. 49, f. 31.

Living—Bodega Bay to San Diego. Panama.

Pl.—San Diego well. Given in Catal. of 1888 as *S. subcoronata*, which is now called a variety of the Panama shell, though specimens have not been found in Mexico.

Quat.—Sta. Barbara to San Pedro.

Stenoradsia magdalensis Hinds.

Zoöl. of Sulphur, 1844, p. 54, pl. 19, f. 1.——Carpenter, Moll. of West. Amer., p. 135 (649).——Dall, Proc. Nat. Mus., vol. I, p. 330, 1878.——Keep, West Coast Shells, p. 107, f. 94.

Living—Monterey to Mazatlan, Mexico.

Quat.—San Nicolas I. (S. Bowers).

Tellina idæ Dall.

Proc. U. S. Nat. Mus., vol. XIV, p. 183, 1891, pl. 6 and 7.——*Tellinella*, No. 63, Geog. Catal., 1867 (J. G. Cooper).

Living—Catalina Island, 16 to 38 fms, young (Dall). San Pedro Bay and Long Beach (Miss Ida Shephard, etc.).

Mioc.?—San Diego, Dall. The young valves found by me in 1863 looked like thin specimens of *T. bodegensis*.

T. diegoana Conrad, fossil, looks like a deformed specimen of this species.

Triton gibbosus Broderip.

Proc. Zoöl. Soc. Lond., 1833, pl. 7.——Tryon, Manual of Mollusca, vol. III, p. 23, f. 103.

Living—West tropical America. Panama.

Quat.—San Pedro? (Found in the bay, and named by Dall as "probably fossil.")

Turcicula bairdi Dall.

Proc. U. S. Nat. Mus., vol. XII, p. 346, pl. VII, 1889.

Living—"Off San Clemente Island, in 414 fms." (Dall).

Quat.—Dead Man's Island, San Pedro Bay (Miss Monks). The specimen sent me is twice the size of Dall's type figured, but otherwise seems to agree closely.

Turritella sanguinea Reeve.

Conch. Icon. Turrit., No. 27, pl. 6, "California," probably meaning Lower Cal.

Living—Cape St. Lucas (Carpenter).

Quat.—San Pedro (Mrs. Williamson and Miss Monks, coll.). Some still retain color, and may be recent. Like enormous *T. jewetti*, one I have being over four inches long.

Pl.?—Sta. Rosa I. (Voy). Specimens appear to run very close to *T. inezana* Con., which was before found there.

RADIATA.

Strongylocentrotus drobachiensis A. Agassiz.

Living—Circumpolar, south to coast of Mexico.

Quat.—San Nicolas Island (Bowers).

ADDITIONS TO CRETACEOUS CATALOGUE.

Actæonina californica Gabb.

Cret.—Near Yreka. Oregon. Benicia, Solano County. Martinez, Contra Costa County.

Asaphis multicostata Gabb.

Pal. of California, vol. II, p. 189, pl. 29, f. 70.

Cret.—Crooked River, Eastern Oregon (Gabb). Santa Ana Mts., Orange County (S. Bowers).

Clisocolus cordatus Whiteaves.

Geol. Surv. Canada, vol. I, p. 157, pl. 18, f. 3.——White, Bulletin U. S. Geol. Survey, No. 51, p. 41, pl. VI, f. 89, 1889.

Cret.—Vancouver I., etc. Santa Ana Mts., Orange County (S. Bowers).

Galerus excentricus Gabb.

Pal. of Cal., vol. I, p. 136, pl. 20, f. 95; pl. 29, f. 232 (omitted in Catalogue of 1888).

Cret. B.—Martinez, Contra Costa County, to Tejon, Kern County (Gabb). Santa Ana Mts., Orange County (S. Bowers).

Pholadomya sonorensis Gabb.

Pal. of Cal., vol. II, p. 265, pl. 36, f. 12.

Cret.—Arivechi, Sonora, Mexico (A. Remond). Santa Ana Mountains, Orange County (S. Bowers).

Tapes hilgardi? Shumard.

Trans. St. Louis Acad. Sciences, 1860, p. 601.——Gabb, Pal. of Cal., vol. II, p. 265, pl. 36, f. 13.

Cret.—Texas (Shumard). Arivechi, Mexico (Remond). Santa Ana Mts., Orange County (S. Bowers). There is some uncertainty as to this being Shumard's species, and also as to the genus to which it belongs, the hinge being yet unknown. (See also the new species described in the last part of this Bulletin.)

PART IV.

REMARKS ON THE FOSSILS COLLECTED BY DR. S. BOWERS, IN ORANGE COUNTY.

In relation to Dr. Bowers' collections the following observations seem necessary, being called for on account of my identification of the fossil mollusca collected by him:

(1) *Quaternary Deposit.*—That of San Joaquin Bay, containing 60 species, all of which are living along the coast, is undoubtedly of very late date, almost recent enough to be called a raised beach. It is the only deposit of large extent without some extinct species known on the mainland, San Nicolas Island, eighty-seven miles farther west, being the only locality apparently as recently elevated.

(2) *Pliocene Deposit.*—The great shell-bed at El Toro Station, 600 feet higher, appears to be an older uplift, and will probably prove to contain enough extinct species to be called Pliocene, though such have not been identified on account of the bad condition in which they are, the lime being mostly dissolved out of the upper layers. Similar beds exist farther south and north.

(3) *Miocene Deposits.*—The remaining foothills west of Santiago Cañon seem to be decidedly of Miocene age, with numerous characteristic fossils. At one point only, about three miles above El Toro, Alisos Creek has cut down into the Cretaceous formation, and there I found the characteristic Cretaceous fossils given (in part) as from the Santa Ana Mts., in the Catalogue of 1888. (Three Tertiary species from beds above them are also given there.) A portion of them were, however, obtained by Professor Davidson's Coast Survey assistants, on or near the summit of Santa Ana Peak (Mt. Downey), about 1871.

(4) *Eocene* (*or Cretaceous B*).—While only one out of twelve species obtained in the collections of 1872–1874 could be doubtfully referred to this formation, Dr. Bowers' collection contains twelve or more. As, however, he did not observe any line of division separating the strata containing them from the Cretaceous, it is doubtful whether they can be as well distinguished in these uplifted and disturbed strata, as in those at San Diego, where they lie nearly horizontally on inclined Cretaceous.

(5) *Cretaceous* (*A*).—These beds, apparently rich in fossils, seem to contain species from several divisions older than the so-called "Chico-Tejon" groups, but there is a very small proportion of Ammonitidæ,

thus proving them later than the Shasta group, or even that exposed in the old coal mine on Point Loma, San Diego. The *Nautilus texanus* indicates a near approach to the Eocene, *Aturia zigzag*. From the published lists, Dr. C. A. White considers these Chico beds.

Several other Texan and Mexican species seem to occur, confirming the belief in a free connection of the two oceans existing across Northern Mexico, if not Arizona, in the Cretaceous age. Further collections may prove some of these to be distinct species. It is proper to mention that Professor Davidson's party gave the first notice of Cretaceous fossils on the Santa Ana Mountains to Professor Whitney, then State Geologist, who directed Mr. Goodyear and myself to look for all fossil localities during a rapid journey we were to make by wagon through the Julian gold mines, and thence north to Los Angeles. On account of the suspension of the Survey, no account of these and other discoveries was published until 1888, when Mr. Goodyear gave his observations in the Report of the State Mineralogist, p. 335, including the determinations of the geological age of the strata along the route as shown by the fossils, etc. Alisos Creek was the only locality north of San Diego where any Cretaceous (or Eocene) fossils were seen. Limited time did not permit of much exploration, nor of making large collections.

Dr. C. A. White is of the opinion that the Cretaceous fossils of the West Coast are all distinct species from those of the Atlantic Slope, and that no connection between the oceans existed in North America during that era.

But the many species of fossils which are so closely allied as to appear merely varieties of each other on the two slopes, and some even identical, the near approach of Cretaceous strata together from each side, and the general law of geology that the oldest formations contain the most widespread species, seem strong arguments against such a conclusion. The same theory was once held by Dr. Gould and others regarding living species, but time has disproved it, and shown that even the narrow barrier of the Isthmus of Panama did not exist until the Pliocene epoch, at least as far as the evidence of Miocene fossils then uplifted can be conclusive.

PART V.

DESCRIPTIONS AND FIGURES OF NEW SPECIES OF CRETACEOUS AND CRETACEOUS B (OR EOCENE) FOSSILS OF CALIFORNIA, WITH NOTES ON TERTIARY SPECIES.

With six plates, and a Catalogue of San Diego County Cretaceous and Cretaceous B or Eocene Species.

I. CRETACEOUS AND CRETACEOUS B OR EOCENE.

REMARKS ON THE FOSSILS COLLECTED BY W. L. WATTS.

The first group of species here described and figured belongs to the division named by Professor Gabb, "Cretaceous B," which has been generally considered by other authorities as representing or including all of the "Eocene" yet discovered along the West Coast. There is, indeed, no constant line of division either in the stratigraphy or the palæontology, by which Div. B can be constantly separated from the undoubted Cretaceous strata beneath it, unless we make an arbitrary rule excluding from the Cretaceous all strata in which no Ammonitidæ are found. There we find the difficulty confronting us that a large number of species of other families of shells seem to be identical on both sides of this line of division. It is, however, possible that comparison of better specimens may yet prove some of these species to be different, and that others have been accidentally buried in the newer strata by being washed out of the older ones where before imbedded. It is certain at least that the two localities from which Mr. W. L. Watts obtained the specimens described, furnish no Ammonitidæ, but this may be explained on the theory that they represent shallow water deposits close to a seashore or estuary, in which large quantities of vegetable matter from the land were accumulated. Both the probable habits of the species found at the coal mines near Huron, Fresno County (as compared with nearly related species), and the presence of coal in the rocks containing them, point to such a conclusion, and the occurrence of many of the same species, together with a thin bed of coal somewhat farther away, indicate that the species from Marysville Buttes inhabited a similar but somewhat deeper sea. There is much reason to believe that it was a deep inlet like the Gulf of California, or perhaps a more open channel connected with others running among islands which formed the commencement of the present Coast Range.

There are several other species believed to be new in the collection, which are not perfect enough for description. It is a notable fact that in both localities mentioned the conditions for perfect preservation of specimens are much better than usual in the Cretaceous strata, as little or no metamorphism has occurred, and softening of the shells is quite moderate, though rather troublesome at the coal mines. The presence of Conrad's "finger-post of the Eocene" (*Cardita planicosta* Lamarck, as recently confirmed by Dr. White, from Oregon specimens) abundantly, at Marysville Buttes, is a strong mark of the Eocene age, and it was not found at the Huron coal mines, though it is given by Gabb as from New Idria, Tejon Pass, etc. I found it myself at San Diego in strata quite above the ammonite-bearing coal mine, and unconformable with it.

ON COLLECTIONS BY H. W. FAIRBANKS.

After the preceding remarks were written, and while the new species were being prepared for illustration, Mr. Fairbanks brought in his large collection from Cretaceous (Eocene ?) and Tertiary strata of San Diego County, containing large additions to the known lists from that county, and a considerable number of new species in the Cretac-Eocene divisions. Having carefully avoided mixing those from various localities, Mr. Fairbanks' collections proved of great value as evidence in the much-debated question as to the continuity of the two formations referred to, and I have therefore tabulated the results, so as to show how far each species is found to be contained in the true Cretaceous or ammonitiferous beds. The extent of the Cretaceous B, or Eocene strata of different authors, is not great in that county, but they are very productive of species of fossils, and therefore seem to indicate the lapse of a long period of time during their deposition—as long, perhaps, as the whole of the Tertiary and Quaternary epochs combined, as demonstrated by the marine deposits hitherto known on this coast. The only "Cretaceous" fossils previously published as from San Diego County were those which I collected, described by Mr. Gabb in the Palæontology of Whitney's Geological Survey of California. They were obtained: First—From a shaft sunk for coal near the lighthouse on Point Loma; a *Heteroceras*, preserved and presented by E. W. Morse, Esq. Second—*Baculites chicoensis*, found by me loose on the surface near the lighthouse (where I searched unsuccessfully for others). Third—A few species presented by Mr. Morse from an unknown locality, and which were perhaps in part Tertiary. Fourth—Over 20 species collected by me at one locality, a branch of Rose Cañon, seven miles north of Old San Diego, but which were all included by Gabb as Cretaceous fossils. It must also be noticed that in Vol. I of Pal., p. 220, Mr. Gabb tabulated twenty-one of these, and gives seven of them as from "Cret. A" beds, while in fact all but the two named above, and "*Gryphœa vesicularis* Lamk," were from the one bed mentioned, and therefore of "Cret. B." Ten of these species are not contained in Mr. Fairbanks' collection, although large, and from very near to the same localities, showing what a great variety may be found in a very limited range. On a second visit to the region in 1872 I collected another series only three miles northward, where Rose Cañon enters Soledad Cañon, and all I could identify of them were included in the localities given with the Catalogue of Californian Fossils, published in the Report of the State Mineralogist for 1887. Nine of these were also absent from Mr. Fairbanks' series from six localities. In order to exhibit the subject in full I have added these 19 species to the table, in columns headed "Cooper's Collection," and "Near Soledad." His additions to the true Cretaceous fossils were the most important, being 44 from the west base of Point Loma and from La Jolla, besides 10 supposed to be new species. To the 37 before known from Div. B he added 15, and 6 new ones. The proportions are now 51 in Div. A and 57 in Div. B, a very close balance for comparison of the two, but it does not exactly express their numbers, as several (about 10) are found in both, and this table only shows how they appear successively in ascending from the lowest bed at Point Loma to the highest northward. In other parts of the State many of the same species have been found in different beds, as referred to in the Catalogue of Californian Fossils mentioned above. These references are included in the first two columns of the table.

In the Catalogue I also mentioned three Cretaceous species which I found near San Luis Rey, and these were the first found so far north of San Diego Bay (belonging to Div. B); but they were so imperfect as to cause doubts of their true age until confirmed by the finding of [illegible] more species there by Mr. Fairbanks. From there the Cretaceous strata strike due north through the Santa Ana Mountains, being concealed along the coast by Tertiary beds, except at one spot on the west slope of the mountains, where Alisos Creek cuts through the Tertiary, eight or ten miles from the beach in Orange County. Dr. Bowers found fossils of both Div. A and B in the Santa Ana range, but could not perceive any line of demarkation or unconformability between them.

Though he met with four or five new Cretaceous species, the specimens are generally too imperfect for description or illustration, only two being here described.

CRETACEOUS AND EOCENE (CRET. B) FOSSILS.

Terebra wattsiana n. sp. (Pl. I, Fig. 1.)

Whorls regularly tapering, about fourteen (upper three or four lost); flattened, slightly turreted by narrowing in front, the highest with about twenty-three narrow, close-set riblets crossing their whole width vertically, and increasing to about fifty on body-whorl. Base and columella smooth, mouth normal, canal much twisted, notch deep. Length, about 1.75 inch; breadth, 0.45; mouth, 0.4; width, 0.10. More robust, larger, and fewer-whorled than *T. californica* Gabb, also of Div. B, but nearly allied to that species. A single specimen only was found at Marysville Buttes by Mr. W. L. Watts.

Surcula crenatospira n. sp. (Pl. I, Figs. 2, 3, 4.)

Nuclear whorls three, smooth, large, the apical immersed; other spiral whorls five, turreted, gradually enlarging, each with about nine rounded tubercles horizontally flattened, forming a chain around the middle, and connected by two strong revolving ribs, making a sharp angle. Above this are five or six fainter ribs, crossed by strong sinuated lines of growth, and below a similar sculpture, the whole surface being thus divided by strong reticulations, extending forward on body-whorl about half its length. Mouth simple, sinus moderate above angle, canal long, straight, aperture as long as spire. Length, about 1.75 inch; breadth, 0.80; mouth and canal, 1 inch long, 0.40 wide.

Not very near any of Gabb's species of the family, except in the long canal, which seems to have been more common in the fossil than in living *Pleurotomidæ*. The character of the sinus and sculpture ally this and some of the following to the sub-genus *Clathurella*, though according to those who classify by the soft parts, such divisions are of little value. They must be taken for all they are worth in fossil species, as necessary divisions, in the absence of better ones.

Quite common at Marysville Buttes, where Mr. Watts and Mr. Ullrey obtained 35 specimens. A very similar species inhabits the West Coast of Mexico at present (*S. olivacea* Sby.).

Surcula monilifera n. sp. (Pl. II, Figs. 28, 29.)

Fusiform; nuclear whorls three, smooth, conical; the next crossed by twelve or more strong, oblique riblets, which change on fourth or fifth into a row of beaded knobs, forming an angle along middle of whorls, increasing to thirty-five on ninth or body-whorl. Above this angle are nine or ten fine revolving riblets, and three or four below it, the two posterior being longest, and imperfectly beaded at the suture. On the anterior whorls the medial knobs are sometimes doubled, and on the body-whorl the revolving riblets are alternately large and small. Canal straight, equaling the sub-oval mouth in length. Sinus deep, situated at the angle. Length, 0.60 inch; breadth, 0.08; mouth and canal, 0.34 long.

Five specimens obtained, agreeing well in characters, at Marysville Buttes, by Mr. Watts. This is quite near to Gabb's "*Turris claytonensis*," from near the Mt. Diablo coal mines, but a comparison with his description shows marked differences. Figures twice the natural size.

The occurrence of seven new *Pleurotomidæ* without many other univalve shells, and especially the absence of the many forms of genera allied to *Fusus* described by Gabb, is a condition of distribution indicating probably that a warmer sea existed where they are found, than at most localities of similar age in California.

Surcula inconstans n. sp. (Pl. II, Figs. 20, 21.)

Shell long, fusiform, whorls about ten, the first two turbinate, smooth; third to sixth with ten or twelve transverse close-set ribs, which, on the other four whorls, show only on the posterior half of each, being replaced by eight or ten revolving riblets, forming a cancellated sculpture near middle, and toward the canal appearing alone. Mouth narrow, sinus at angle, canal long. Length, 1.10; breadth, 0.25; mouth, 0.50 inch. The figure is double the natural size.

Pleurotoma perkinsiana n. sp. (Pl. II, Figs. 23, 24.)

Very long and slender; whorls about ten, rounded, the first two turbinate, smooth; third with ten or twelve close-set vertical riblets, crossed by eight or ten revolving ones, the vertical gradually increasing to twenty-six on the body-whorl, forming a close beaded sculpture as far as the middle of body-whorl, while the revolving ribs continue alone on the body to canal. Varies also in relative strength of the two series of riblets, at different portions of spire. Sinus close to suture, canal straight, columella simple. Length, 0.60 inch; breadth, 0.15; mouth, about 0.25 long, 0.09 wide. This and the preceding have many characters alike, and are both variable in similar directions, so that at first they seemed varieties of one species, but the position of the sinus and differences in size and form distinguish them. Two specimens found at Marysville Buttes by Mr. Watts are figured; twice the natural size.

Pleurotoma decipiens n. sp. (Pl. II, Fig. 32.)

Outline rhomboid; whorls seven (the first two imbedded in rock), fifth to seventh sharply angled near middle, concavely sloping to the suture behind the angle, flattened in front, body-whorl rounded in front, forming nearly half of total length, and suddenly narrowing into a canal as long as body-whorl; surface crossed by numerous vertical raised lines, curved backward above the angle, straight below it, and crossed by three or four fainter revolving raised lines. On body-whorl the latter are stronger, about ten below the angle, and continue spirally to the end of the long canal. Mouth not seen. Length, about 0.85 inch; breadth of body-whorl, 0.35; canal, 0.25, with body-whorl, 0.50.

This shell appears much like some of the family *Aporrhaidæ*, but no evidence of expansions around the mouth was found, and it has a distinct sinus above the angle. Only the one figured had shell remaining, but several casts were also found in Rose Cañon by Mr. Fairbanks.

√ **Drillia ullreyana** n. sp. (Pl. II, Figs. 25, 26.)

General form oblong-rhombic; first three whorls smooth, conical; fourth with seven strong knobs crossing it, and continuing on the six following at regular intervals; crossed by about ten fine revolving riblets above the middle, and four stronger ones below, increasing to about thirty of uniform size on the body-whorl and canal. Mouth nearly half of whole length, acute posteriorly, with a slight angle on upper third. Canal tapering, straight, sinus deep behind angle. Length, about 0.66 inch; breadth, 0.30; mouth and canal, 0.35 long, 0.12 wide. Marysville Buttes, Mr. Watts; four similar specimens.

The canal is long for a *Drillia*, but not more so than in *D. raricostata* Gabb, which this much resembles, differing in having the knobs more numerous, shorter, and broader. The figures are twice the natural size.

√ **Mangilia suturalis** n. sp. (Pl. II, Fig. 27.)

Form lanceolate; nuclear whorls three, fourth with ten strong vertical riblets, continuing on next five whorls, but decreasing to six on body-whorl; crossing entire whorl, but higher at middle, forming an obtuse angle, marked by a strong revolving riblet; one strong riblet parallel to this close to the suture, and one below angle. On the body they increase to over twenty of uniform size. Strong lines of growth cross these throughout, showing a deep sinus, mostly posterior to the angle. Canal slightly twisted. Length, 0.55 inch; breadth, 0.08; mouth, 0.29 long, 0.06 wide. Two specimens found at Marysville Buttes by Mr. Watts, and one illustrated here of twice the natural size.

√ **Cordiera gracillima** n. sp. (Pl. II, Fig. 22.)

Very slender, fusiform; first two whorls smooth, turbinate; third with about twelve oblique subvertical riblets, which decrease to seven on sixth whorl, narrow, meeting at sutures, and with four revolving riblets crossing them, one along suture. A wide interval between this and the next anterior, forms an obtuse angle on whorls, continuing to the upper third of body-whorl, below which the vertical ribs disappear. On body-whorl about eight revolving riblets cross these, with three or four fine ones between each, and twelve to fifteen others below angle pass around the canal. (The shells being imbedded in rock the exact number of vertical ribs cannot be distinctly seen, whether seven or eight, and the outer lip is too much broken to see the form of the sinus, but it must be very shallow.) Mouth very narrow, sharp above, widest at angle of lip, below curving to the left, gradually forming the canal. Columella with four plaits at middle, the upper one strongest. Length, 0.48 inch; breadth, 0.09; mouth, 0.14 long, 0.03 wide; canal, 0.10 long.

The figure is twice the natural size of the one specimen found at Marysville Buttes by Mr. Watts. This is a decidedly different shell from the two species figured and described by Mr. Gabb, both of which were also found in Santa Ana Mountains, Orange County, by Dr. Bowers, but in a very poor condition.

Cancellaria irelaniana n. sp. (Pl. I, Fig. 5.)

Shell oblong fusiform; spire of eight whorls, the first three nuclear, smooth, conical; fourth with nine prominent vertical ribs, abruptly truncate at sutures, and continuing thus on next three whorls, but on eighth whorl becoming conical, tubercles at posterior margins, more distinct on body-whorl, the ribs disappearing. The three anterior whorls show strong vertical lines of growth, or irregular sculpture, which above the tubercles is crossed by three or four revolving raised lines. (Outer lip broken off for about half an inch.) Columella with four very strong and three fainter oblique folds (or ribs). Length, about 1.75 inch; breadth, 0.75; mouth, 0.87; width, (?).

Only one specimen found at Marysville Buttes by Mr. Watts. This shell is nearer to the sub-genus *Narona* than to any of the allied forms, and in its spire much resembles the species living on our coast, *C.* (*N.*) *cooperi* Gabb. Though Mr. Gabb described a Tertiary species as *C. vetusta*, thus suggesting its absence from the Cretaceous strata, we have here a proof of its presence in the Eocene or Cret. B strata.

Genus, **Ancilla** Lamarck. **Oliverato,** nov. sub-genus.

Sub-Generic Characters.—Young shell resembling an *Oliva*, with three nuclear turbinate whorls, the next three rapidly enlarging, forming a conical spire, which becomes nearly buried by callus in the adult; the seventh whorl as in young *Cyprea*, etc. The eighth whorl, instead of growing longer, increases chiefly by enveloping and thickening the body of the shell, the deposit of callus forming two thickened layers on the sides of shell, extending toward the middle of back as the animal grows older, but rarely meeting, or only as a thinner layer in the middle, and burying half the spire in its growth. Section of shell thus forms an obtuse triangle as in some *Cypreas* (one specimen only being circular in section). Surface smooth, often retaining high polish, even in the fossils. Outer lip thickening moderately, leaving the mouth lateral, much as in *Erato*, differing in non-crenulated lips, and in the form of anterior notch, peculiar dorsal canal, etc. Its relations to other genera are evident, and show very interesting stages of development between them. No distinct folds or denticles on columella or lip at any age.

The animal evidently widened the mouth by absorption while thickening the shell on outside, and finally attained nearly the form of *Erato*. Posterior angle of mouth deeply notched, and anterior end forming a deeply notched canal, slightly turned upward. Found only near Marysville Buttes, Sutter County, by Mr. Watts and Mr. Ullrey. Eight specimens obtained. "*Ancillaria glandiformis*" Lamarck, fossil, may be congeneric.

A. (Oliverato) californica n. sp. (Pl. I, Figs. 6 to 10.)

About half of spire (the nuclear whorls) invisible in adult; mouth with lips nearly parallel at middle; narrower at ends in the young, with about ten faint ridges along columella, not passing inside; no umbilicus. Dorsal surface marked by ridges from irregular thickness of the callus, and a deep oblique furrow running from the anterior notch toward the left, as in *Pseudoliva*, etc. Parallel to this, about six light ridges remain permanent behind it, thickened but not obscured by callus. General form becoming more ovate with age, but always narrower in front. Length, about 1.50 inch; breadth, about 0.85; mouth, 1.12 inch long, 0.50 wide. Eight specimens examined.

Four of the specimens are polished and colored a fine brown, just as in the living *Erato vitellina*. This color is confined to a thin outer layer of the callus, as shown in the dorsal figures.

Bittium longissimum n. sp. (Pl. II, Fig. 30.)

Exceedingly long compared to its diameter; first three or four whorls regularly convex, smooth; the remaining thirteen with ten to fourteen vertical riblets crossed by three revolving ones, which cancellate the surface uniformly; the anterior riblet largest, thus giving the whorl a turreted form; mouth quadrilateral, simple (the basal surface cannot be seen). Length, 0.45 inch; breadth, 0.06; mouth, 0.03. The shell had at least sixteen whorls, and the smoothness of the upper ones may be due to erosion. It much resembles the living *B. asperum* Gabb (stouter with thirteen whorls), a variety of which is also turreted. (See Pal. of Cal., II, p. 12, pl. 2, f. 20.) Marysville Buttes, only found by Mr. Watts. Figure twice the natural size.

Cerithium fairbanksi n. sp. (Pl. I, Fig. 12.)

Shell large, turreted, (first two or three whorls wanting); next rounded, with about nine vertical ribs, very prominent at middle, and crossed by six or seven revolving grooves. Three anterior whorls so broken that the vertical ribs are gone, except at sides where they appear as sharp varices, the eight or nine grooves crenulating their edges, and well separated by the sutures; the revolving grooves extend to base of shell at edge of canal (which is broken off). Base with four or five unequal ribs.

Mouth sub-oval, outer lip crenulate; columella, ——. Length, nearly 2 inches; breadth, 0.85; mouth, 0.40; width, 0.35. This was one of the tropical forms, and more ornamented than the *C. mexicanum* Gabb, from Sonora. It seems likely that varices extended the whole length on each side, as in *C. echinatum*, but were not continuous. Only one specimen found, half imbedded in hard rock, and the surface much worn off. It was discovered by Mr. Fairbanks, at the west side of Point Loma, San Diego, in the stratum of Cretaceous A.

Potamides carbonicola n. sp. (Pl. I, Figs. 14 to 19.)

Form columnar, slowly tapering (first whorls eroded); third or fourth strongly sculptured, with twelve to fifteen subvertical ridges, curved toward the left, and crossed by three revolving ridges, causing a cancellated surface. The ridges vary in development on different parts of one shell, as well as on different specimens. Sometimes one and sometimes the other set of ridges has the most strength, and often one or two of the revolving ones being higher than the third, causes an angular projection either at middle of whorl or along the suture, the whorls being flat when all are equal, and twelve or more in number. No thickening of lips or varices shown in the specimens. Length, 1.50 inch; breadth, 0.50 to 0.75; mouth, 0.12 long and wide.

This shell, like other Potamides, evidently inhabited a muddy bay, in which fragments of coal were mixed with mud, and the matrix now contains them in great quantity, the shells being often filled with the black mixture.

They were also gregarious, as is *P. californica* in our bays, but from their fragility it is very difficult to obtain whole ones. Several are figured to show the variations of surface.

Head-wall of "California Coal Mine," near Huron, Fresno County, east slope of Mt. Hamilton range. Cret. B, Mr. Watts.

Potamides? davisiana n. sp. (Pl. I, Fig. 13.)

First three whorls convex, turbinate, smooth; the next six turreted, increasing rapidly by wide, flattened expansions of the upper surface of whorls, with a sharp raised carina half-way between the sutures, from which the surfaces above and below diverge at a right angle. Fourth whorl ornamented with about forty fine sharp riblets, strongly curved to the left, above the carina, and giving it a serrate edge, then passing down to the next suture. On the sixth whorl they are crossed by two revolving riblets below the carina, and on the seventh or body-whorl these increase to fifteen or more, with many intermediate smaller ones, which finally entirely efface the vertical lines. Mouth triangular, simple, inner edge of outer lip crenately notched, thin; (columella and canal lost). Length, 1.16 inch (or more); breadth, 0.70; mouth, 0.50 long, about 0.35 wide. The backward curve of the growth lines above the carina suggests a Pleurotomoid shell, which is partly confirmed by the curve forward of the posterior margin of outer lip remaining, but the general form is so similar to that of Gabb's *Potamides diadema*, that I have placed it in that genus until better known. (See Pal. of Cal., I, p. 130, pl. 20.) Resembles *Pleurotoma* (*Perrona*) *spirata* Lamk. Marysville Buttes, one specimen from Cret. B, Mr. Watts.

√ **Fusus supraplanus** n. sp. (Pl. II, Fig. 31.)

Slender, whorls ten, rounded, regularly tapering to an acute point; the ninth with five revolving ribs, deeply separated by narrow grooves; upper fourth of whorl smooth, and slightly concave-tabulate; body-whorl over half of length, with ten revolving ribs, and tabulated above; canal as long as body-whorl, straight, acute. The matrix of the seven upper whorls shows traces of obliquely vertical embossed sculpture, forming about twelve knobs on the seventh. Some traces of them are also preserved on another specimen retaining more of the shell, from which the sculpture of the body-whorl is also taken. Mouth imperfect. Length (of figured one), 1.15 inch; breadth, 0.32; canal, 0.28. Nearest to *F. flexuosus* Gabb, with more and narrower whorls, straight canal, and different sculpture. Many casts occurred in the Rose Cañon bed, but none quite perfect. The best as to surface characters, but with only four whorls, must have been twice as large as that figured. Mr. Fairbanks also found some in the False Bay bed, San Diego. Cret. B.

√ **Mitra simplicissima** n. sp. (Pl. III, Fig. 41.)

Shell fusiform, whorls six or seven; body-whorl about equal to spire, sutures lightly impressed; surface shining, with very faint revolving striæ, stronger toward the canal. Mouth narrow, acute above, with three or more strong columellar folds near its middle. (The one figured is broken, but a smaller one gives a dorsal view of the anterior end.) Canal slightly twisted. Length, about 0.60 inch; breadth, 0.25. No traces of larger specimens occurred, yet they may be expected to be found, as the species is scarcely distinguishable from the young of *M. maura*, a common species living in the same region, which grows 2½ inches long. Like *M. cretacea* Gabb, which he calls the oldest known of the genus, it is small and even simpler in form than that species. Two only were found in Rose Cañon by Mr. Fairbanks. Cret. B.

Stomatia intermedia n. sp. (Pl. III, Fig. 43.)

Shell haliotiform, whorls two or three, flattened, rapidly expanding, with four strongly carinate ribs revolving above the margin and one or two below it; the outer ones sometimes forming an undulating margin toward the anterior end. Interspaces sub-equal, slightly concave, with revolving ridges near apex, crossed by irregular radiating lines of growth. The sculpture is sometimes scaly or imbricated. Apex distant from margin, the outer whorl forming an expansion along the posterior margin, equal to one sixth of the length of shell. Length, 1 inch or more; breadth, 0.90; height, 0.35. One specimen, half grown, retains a reddish color on the surface, and more perfect sculpture, looking like a *Haliotis rufescens*, without the perforations. Only five specimens found, in Cret. A, at the west base of Point Loma, San Diego.

The figure is made from a combination of three specimens, as none singly shows all the characters of the species.

Resembles the *S. suciensis* Whiteaves, of the Vancouver I. group, and is possibly a connecting link between that and var. *carinata* Wh., but seems more likely to be quite distinct.

Calliostoma kempiana n. sp. (Pl. III, Figs. 33, 34.)

Shell with a conical outline, higher than wide, imperforate; whorls six or seven, flattened, with strong vertical ribs closely arranged. Basal margin crenated by the ribs; the surface with about ten concentric riblets. (Mouth and columellar region concealed by the matrix.) Height, 0.50; breadth of base, 0.44.

Three specimens found at the west base of Pt. Loma, by Mr. Fairbanks. This species seems quite different from *C. radiata* Gabb, which was from still older beds.

By request of Mr. Fairbanks, I have named this handsome species in honor of his wife, formerly Miss Kemp, who has taken much interest in fossils, and assisted him in scientific work.

Tornatella normalis n. sp. (Pl. III, Figs. 36, 37.)

Shell oliviform, whorls six, apical subacute; next four gradually enlarging, with five to ten sharply-impressed grooves parallel with the sutures, which are also rather deeply impressed; body-whorl with about fifty similar grooves, crossed by irregular lines of growth, ending anteriorly in an obtuse point. Mouth subovate, acute posteriorly; columella with one basal plait. Length, 0.65 inch; breadth, 0.25; body-whorl, 0.50 long.

This shell does not closely resemble Gabb's species from the older Cretaceous, nor Dr. White's from the same beds. It is more like the living *T. sulcata* Lamarck, and others. Yet it was found in the Cretaceous A bed, at the west base of Pt. Loma, by Mr. Fairbanks, together with Ammonites, etc. Two specimens are very perfect.

√ **Bulla assimilata** n. sp. (Pl. IV, Fig. 46.)

Form oval, narrower anteriorly; mouth little longer than spire; outside smooth, shining; lines of growth faint, slight malleations visible with a lens; color pale brown, with irregular fleckings of darker tint scattered throughout. Length, 0.75 inch; breadth, 0.50.

Very similar to *B. adamsi* Menke, found living in the same region. That is, however, broader anteriorly, as in other living species. The preservation of color is remarkable for a fossil of such age, and although the specimens are imbedded in very hard stone, the single whole one may be a distorted specimen of Quaternary date, from a raised beach which exists above the Cretaceous in spots. Several living species, with their colors, are found in that bed, which cannot be distinguished from the Cretaceous below in lithological characters, among which were identified *Haliotis cracherodi*, *Leptothyra carpenteri*, and others still living. As they do not continue into Div. B, there is no further evidence of their being Cretaceous species. The form of this shell is like that of a young *Cyprea*, but its coloration is that of a *Bulla*.

√ **Tornatina erratica** n. sp. (Pl. II, Fig. 35.)

Form cylindrical, whorls five, the first immersed, second helicoid, next two rapidly enlarging, and deeply channeled at sutures; fifth diverging suddenly in a loose spiral, the suture advancing ¼ of an inch in one revolution; mouth very long and narrow, lips simple, surface smooth, chalky white. (Anterior end of shell broken off.) Length, 0.70 inch; breadth, 0.25. A thin external layer of shell is gone, as shown in the matrix filling mouth, but this was smooth as far as visible.

Siphonaria capuloides n. sp. (Pl. II, Figs. 38, 39.)

Base broadly oval, dorsally curved backward, beak projecting horizontally beyond posterior margin. Anterior surface with eight radiating ribs, from apex to base, and two or three intermediate short ones. Four or five posterior ribs at wider intervals. Extreme apex broken, but was acute, and slightly turned to right, on which side is a sharper rib, probably marking the siphonal groove; but opposite is also an obtuse angle, the two separating the anterior third from the dorsal two-thirds. The strong ribs on this specimen (which is only a cast) indicate probably a thin shell, with similar sculpture. It has about the form of Say's figure of the Atlantic *S. alternata*. Length, 0.65 inch;

breadth, 0.55; height, 0.25. Two casts found at base of Pt. Loma, by Mr. Fairbanks, in Cret. A. Fragments of shell also found, which seem to have belonged to this species.

Astarte semidentata n. sp. (Pl. III, Figs. 44, 45.)

Subtrigonal, nearly equilateral; posterior margin slightly curved, obtusely angled; basal little more convex, sharply curved upward anteriorly, half the height of shell; thence deeply excavated to beaks, which bend strongly forward. Lunule long and deep, nearly half the length of posterior margin. Hinge-area broad, the posterior half of it a flat, shallow pit (in the left valve); two strong teeth, with the triangular pit filling anterior half. Lateral teeth very weak, pallial line deeply impressed. Surface slightly convex, with shallow transverse grooves near the beaks, becoming obsolete on lower half of disk. Length, 0.90 inch; height, 0.80; diameter about 0.40 (both valves). Three specimens found in Cret. B, in Rose Cañon, by Mr. Fairbanks. This species seems to differ more in the hinge than in other features from some living species. Its hinge approaches that of *Crassatella*, forming a connecting link.

Crassatella lomana n. sp. (Pl. III, Fig. 47.)

Shell large, wedge-shaped, thick, more or less angled on the posterior dorsal surface; disk marked only by coarse lines of growth; anterior end truncated nearly at a right angle to dorsum; umbos nearly meeting, and dorsal area deeply hollowed behind them. Lunule not impressed, lower half of front obtusely rounded, curving under to the nearly straight basal line, which posteriorly bends upward suddenly to form the narrow wedge-shaped extremity. Dorsal ridges forming obtuse angles from the umbos to the upper edge of wedge. Under layer of shell with fine radiating striæ; inner margins of valves coarsely crenulate. Thickness of shell, about $\frac{1}{8}$ inch; at umbos, $\frac{1}{4}$ inch. Length, 3.50 inches; height, 2.20; diameter, 1.38.

Six specimens were obtained at Pt. Loma, in Div. A, by Mr. Fairbanks. At first I thought it a variety of *C. tuscana*, which is found with it, but it shows no trace of the concentric ridges of that species at any age, and differs too much in size and form. The radiated undershell is found in both. I could not obtain a good view of the hinge, but there seems every reason to consider it a *Crassatella*, in which opinion Dr. C. A. White agrees with me.

Cucullæa bowersiana n. sp. (Pl. V, Figs. 61, 62.)

Shell large, thick, nearly equilateral; surface smooth, or with coarse lines of growth; valves very convex, sub-truncate posteriorly, but with edges of valves prominent, rounded; umbonal ridge obtuse, nearly straight; beaks moderate, meeting in a medial line; anterior outline slightly incurved above, but rounded on lower half; base moderately curved, rounded posteriorly. Length of largest, 2.50 inches; height, 2; diameter of shell, about 1.20. Truncation quite variable. As the many specimens obtained did not agree with any described by Gabb, and were accompanied by many of his *C. inermis* and *C. mathewsoni*, I suspected them to be the *C. æquilateralis* Meek, described from the Cretaceous of Vancouver I., B. C. On sending one to Dr. White, in Washington, to compare, he decided it was different, and could give no name for it. Cretaceous of Santa Ana Mountains, Orange County, Dr. S. Bowers. The collections made in that most southern locality in which Ammonites have been found in California (except the old San Diego coal mine), were enumerated in the Report of the State Mineralogist for 1890. There were several other species which may prove new, but in too imperfect a condition to describe. The "*Exogyra costata* Say" of the list proves not to be that, but the species is uncertain.

√ **Corbula triangulata** n. sp. (Pl. IV, Fig. 42.)

Shell doubly trigonal, higher than long, with four nearly equal triangular surfaces. Valves equal, the disks being nearly right-angled triangles, higher than wide; the beaks prominent, acute; anterior margin slightly incurved; posterior straight, more acutely ridged laterally; surface crossed by about thirty undulations, parallel to lines of growth. Basal margin moderately curved. Anterior face of shell triangular-cordate, slightly concave, with edges of valves projecting vertically in upper half. Posterior face similar, but twice as large; concave above, and edges of valves less prominent; central area convex, and umbonal ridges forming a sharp raised margin on each side. Hinge unknown. Length of base, 0.30; anterior height, 0.30; posterior, 0.40; breadth, 0.30; at umbos, 0.20.

This curious shell was found by Mr. Fairbanks only at base of Pt. Loma, in Cret. A, and only the entire shell described occurred, with one other broken valve. I was therefore doubtful whether to call it a *Corbula* or *Nucula*, or something else, but finding that Conrad has described somewhat similar Tertiary species, as *Corbula curta* and *C. elevata*, from Maryland, I venture to propose the above name. When the hinge can be examined, a subgeneric name will probably be found advisable.

√ **Mytilus dichotomus** n. sp. (Pl. V, Fig. 64.)

Very similar to "*Septifer dichotomus*" Gabb, but without any trace of a septum inside the beaks. Outside also sculptured, as in *Modiola ornata* Gabb, and in several Tertiary or living species of this family. (Unfortunately the umbonal end of the specimen figured was broken off after it was arranged for drawing.) I illustrate this shell to show that such a *Mytilus* existed in the latest stage of the California coal-epoch, with a strong suspicion that it has already one or two names. Gabb's *Septifer* was described from one young specimen found at Tejon, very nearly in the same strata, and it is not unlikely that he was mistaken in the generic character, but if proved correct the specific name suits this species as well. There is also Conrad's *Mytilus inezensis*, assigned to the Miocene Tertiary, which *prima facie* seems most probable, though there is room for doubt. This has not lately been confirmed among large numbers of Miocene fossils handled by me, and if found in the Miocene will probably be found to be the living *M. bifurcatus*, which also has its *Septifer bifurcatus* coexisting. In doubt as to the true value of the slight distinction between the two genera, I leave their correct names to be decided by future discoveries.

Several valves found in the head-wall of the California Coal Mine, near Huron, Fresno County, associated with *Gyrodes dowelli* White, and other species of Cret. B. They had a brown color externally, but were much broken up and fragile, so that no good one could be illustrated.

Crenella santana n. sp. (Pl. III, Fig. 40.)

Shell modioliform, with forty to fifty faint ribs, radiating from the beaks toward the periphery. Beaks about one sixth of total length from anterior end, a little raised; dorsal margin slightly convex; basal a little concave at middle; ends broadly rounded. Length, 0.32 inch; height, 0.20; diameter, 0.12. From base of Pt. Loma; Cretaceous, Div. A; two found by Mr. Fairbanks.

Apparently the same species was found in the Santa Ana Mts., by Dr. Bowers, but they were so eroded that no definite sculpture could be seen, and were three or four times the size of the San Diego specimens.

Megerlia dubitanda n. sp. (Pl. IV, Figs. 48, 49.)

Lower valve transversely oblong, moderately convex; its anterior or basal margin nearly straight; rayed with forty to fifty close-set ribs; outer margins curved downward, chiefly opposite beaks, for one fourth of the circumference. Upper valve more convex, with coarser ribs, only about half as many as above. Beak unknown, not very prominent. A shallow median furrow, with low ridges at sides. Some of the ribs become divided near margin. Height from base, 1.12 inch; length, 1.12; diameter, 0.50. One lower valve is 1.75 long (transversely), 0.50 deep.

The genus is, of course, only surmised from external characters. It is probably different from that of the next species, but both occurred together, especially at La Jolla, in Cret. A, though this was commonest at base of Pt. Loma, Mr. Fairbanks finding six or more valves.

√ **Waldheimia imbricata** n. sp. (Pl. IV, Figs. 50, 51.)

Lower valve subquadrate, moderately convex, a little more prominent at middle; basal margin nearly straight; about thirty low ribs diverging from apex; crossed beyond the middle by six or seven concentric furrows, marking stages of growth, and giving an imbricated appearance. Lateral margins at right angles to anterior, and nearly straight; posterior margin gently rounded, and slightly undulated by the median furrow. Upper valve more convex; ribs fewer and stronger, the median six or seven ribs depressed. Length of base, 0.90; of shell, 1.00 inch; height, 0.50; diameter, 0.50.

The same remarks given with the last apply to this, but it looks very much like some *Waldheimias* now living on the coast. It was found only at La Jolla, by Mr. Fairbanks. At that place a Quaternary raised beach, of materials similar to those of the Cretaceous beds, again encroaches on the latter, containing *Donax californicus*, etc., and the two formations can only be separated by the species of fossils found in them, as far as lithological, if not stratigraphical, characters go. The fossils of Cret. B are, however, mostly absent, and Ammonites are found there.

II. TERTIARY-MIOCENE, AND PLIOCENE.

A. FROM KERN COUNTY.

Mr. Watts collected a large number of specimens in this county, many of which were identified with species still living on the coast; others, with supposed extinct species, already described as fossils, and several appeared to be new. So many Tertiary species are, however, known to still exist on the coasts of Lower California, and to have been described from the living shells, that it is not considered advisable to describe the fossils until they have been compared with the living species from the south, which are imperfectly known, and besides this the fossils were usually in poor condition. A few are excepted, which have before been imperfectly figured, and some described by Conrad. The reasons are given under each species described or figured. There are also two species of *Pinna*, of which descriptions were first published in the Catalogue of Fossils, 1888.

B. FROM SAN DIEGO COUNTY.

The "mesa," or table land, which rises gradually with a gentle slope from San Diego Bay for eight miles northeast, and is then suddenly uplifted by recent volcanic action, its eastern edge resting against igneous rocks, contains abundant fossils, but in such a poor state of preservation where exposed, that it is usually impossible to do more than to ascertain their Tertiary character. The Quaternary fossils near the beach, and the Pliocene obtained from the "San Diego Well," are indeed very perfect, but older ones from farther inland are very poor. From previous collections of these, geologists have classed them as Miocene, arguing that the most inland must be the oldest. Mr. Fairbanks found some very good specimens along the eastern escarpment of the mesa, which seem to show that the whole of it may be considered Pliocene, or at least as belonging to the intermediate beds passing into Miocene. The slightly disturbed strata all along the coast are usually found to be of later date than those much uplifted, judging from the proportion of living to fossil species in them. The large fossil oysters found at the eastern edge of the mesa have been hastily referred to that truly Miocene species, *O. titan* Conrad, but Mr. Fairbanks' numerous and good specimens show that they are as near to the Pliocene species described by Rémond as *O. bourgeoisi*, tending to show a derivation of the latter from the former. I observed a similar form in the Tertiary beds of Alisos Creek, Orange County, in 1872, and gave it the latter name in the Catalogue of Fossils. With this, Mr. Fairbanks found specimens of *Pecten expansus* Dall, which was first described from the San Diego Well, and is also found in another "Pliocene" bed at Soledad Cañon, twelve miles north. There is nothing in the known fossils of the mesa elsewhere to forbid the reference of the whole to the Pliocene.

Another bed of very perfect oyster shells occurs about fifty miles north of the boundary line, and three east of Oceanside, above the Cretaceous (B) strata. These resemble small *O. titan*, but connect it with Gabb's *O. tayloriana*, under which name I catalogued it in 1887 from San Juan Capistrano, twenty-five miles farther northwest. About the northern boundary of San Diego County the Tertiary begins to be more uplifted, and forms short ridges along the coast, in which the strata are much broken up as if by eruptive action. In these the true *O. titan* appears, of its usual enormous size, and other characteristic fossils appear also; the Miocene strata forming several lower ridges, and a great part of the Santa Ana Mountains. It now appears that the *Ostrea tayloriana* is only the young form of *O. titan*. *O. bourgeoisi* approaches the large species of Western Mexico, which has been called a variety of the Atlantic *O. virginiana*.

C. FRESH-WATER SHELLS FROM A LIGNITE BED.

These three species were found by me several years ago, beautifully preserved between the layers of lignite, to which the white shells form a fine contrast. They could be easily outlined on tracing-paper, though perhaps slightly deformed by pressure.

MIOCENE AND PLIOCENE (OR NEOCENE) FOSSILS.

Agasoma Gabb.—This group of species, although not very well defined, and made by its author to include very dissimilar forms, seems to be a good division of what might otherwise be retained in *Purpura.* I propose to add a species, and a sub-genus with another species, possibly however, of different affinities.

✓ **Agasoma barkerianum** n. sp. (Pl. V, Fig. 63.)

Pyriform, nuclear whorls immersed, smooth, next five ornamented by eighteen to thirty-six vertical riblets, crossed by three to eight revolving ridges, giving them a closely beaded surface. On the sixth whorl the vertical are more distant, and change into blunt tubercles at the suture, ten such forming a serrated crown. On the body-whorl this is stronger, forming a series of sharp folds turned back at irregular intervals (which were posterior notches as the mouth grew), and varices running forward from each to the canal, about fifteen in number. The tubercles of the fifth whorl continue in a row around middle of body-whorl, making an angle at each varix. Two other ridges cross the anterior third of dorsum to the end of beak. The whole of the fifth and body whorls are also traversed by fine ridges, both vertical and revolving, forming a fine cancellation, less strong than on the spire. Mouth simple, oval; length, 1.75 inch; breadth, 1.15; mouth, 1.25; width, 0.50; canal, 0.24 wide.

This species much resembles a cast figured in Prof. Blake's report (Pac. R. R. Rept., vol. V, foss. pl. VII, f. 63), except in the canal, given there as straight, and that may perhaps rather be *A. gravida* Gabb, as suggested by him. Fig. 66 resembles the dorsal varices of my species, which are like those often found on *Purpura crispata.* Only two specimens found, on John Barker's ranch, Kern County.

TROPHOSYCON NOV. SUBG.

General form fig-shaped, with a strongly twisted canal; suture plain, no posterior notch. This shell is perhaps as nearly allied to the *Fulgurs* of the east coast as to *Agasoma*, and two fossil species of Florida have a similar double row of knobs, but in the canal it is very unlike them.

✓ **Agasoma? (Trophosycon) kernianum** n. sp. (Pl. III, Fig. 52.)

Shell pyriform, spire very short, first two whorls smooth (eroded), next two lightly sculptured, with revolving ridges from sixteen on the third, to eleven on the upper surface of fourth. A row of about nine prominent vertical tubercles around posterior angle of body-whorl, and seven alternating with them around lower angle, the interval nearly flat. Anterior end strongly twisted in a wide canal (the aperture filled with a hard matrix). Two revolving ridges between tubercles, and six principal ones anterior to them; also two or three fainter ones between each pair, making thirty in all, crossed by the faint lines of growth. Spire, 0.40 inch high; mouth, 1.50 inch long, 0.75 wide; canal 0.40 wide (broken off short). In surface characters it resembles *Fulgur*, with the thick shell and canal of some *Trophons*. The great variations found in different species of *Fulgur*, however, show us that this might as well belong to *Agasoma*. It also resembles some of Gabb's Cretaceous genus *Eripachya* in outlines, but is decidedly Tertiary. It is apparently the fossil figured in Prof. Blake's Report, pl. VIII, figs. 64, 65, and *a*, which Conrad did not venture to name, casts only being figured. Figs. 72 and 72*a*, which he named "*Syctopus ocoyanus*," may represent *a* cast of a young shell, but it is too uncertain a name to be retained. (This is given as *Ficus ocoyanus* in Gabb's list of unidentified fossils, and *Ficula ocoyana* in my Catalogue of Fossils, 1888.) Only one fair specimen found, by Mr. Watts.

FRESH-WATER FOSSILS.

Limnea contracosta n. sp. (Pl. V, Fig. 59.)

Form broadly ovate, whorls five, rapidly enlarging from an obtuse apex, and with convex outlines, to the very large body-whorl, which forms three fourths of the total length, no umbilical fissure visible. Length, 1.20 inch; breadth, 0.75; spire, 0.30.

Specimens found with the two next species in a bed of laminated lignite, discovered about 1868, along the westerly branch of San Pablo Creek, on the stage road just south of Rocky Mound. A thin stratum of lignite underlies several square miles around that locality, but its exact age is still unsettled. On the east are deposits of marine Miocene fossils, on the west altered Cretaceous rocks with "*Aucella piochii*." The lignite may therefore be a deposit formed in a Pliocene lake. None of the other Tertiary fresh-water deposits yet examined in California contain fossils like this. The coal-strata have evidently been uplifted to an angle unusual in Pliocene deposits, but there is nothing to fix the date of the volcanic outburst which is seen in Rocky Mound, three and a half miles distant.

Planorbis pabloanus n. sp. (Pl. V, Fig, 57.)

Form regularly cylindro-spiral, whorls three and a half, slowly increasing, without sculpture, size moderate. Greater diameter, 0.60 inch; lesser, 0.48. The absence of distinctive characters in most of the species of this genus, together with the flattening caused by pressure in the lignitic laminæ, make it impossible to separate this from some other species; but more specimens may distinguish it better.

√ **Anodonta (nuttalliana) lignitica** n. var. (Pl. V, Fig. 58.)

Form oblong-ovate, the ends rather obtusely pointed near their middle, dorsal line straight along the hinge-margin for about one third the total length; anterior end truncately sloping to an obtuse angle of about forty-five degrees near the middle, then curving gradually to the rounded basal margin; posterior end curving upward more abruptly and forming a more obtuse angle above the middle, then concavely incurved upward to meet the straight hinge-margin. Beaks one third the distance from anterior end, umbonal ridge slight, with a narrow compressed area above it, extending backward to posterior angle. Length, 3 inches; height at umbos, 1.50; breadth unknown, but was apparently very slight.

I have made this description as full as possible to show the differences between this and the living *Anodontas* of this State, which I think are well marked, though they are so variable. Some of the fossil forms from the Quaternary of Nevada come nearer to this, however. It is, of course, still uncertain whether it is an *Anodonta*, the hinge not having been examined, but most probably it is a Pliocene Tertiary fossil.

√ **Amnicola yatesiana** n. sp. (Pl. V, Fig. 60.)

Small, sub-globular, slightly tabulated at the upper part of the whorls, spire acute, conical, whorls four and a half, the body-whorl forming two thirds of whole length, obtusely rounded at base. Mouth suboval, a deep umbilical pit behind columellar lip. Length, 0.11 inch; breadth, 0.08; spire, 0.04; mouth, 0.06 long, 0.04 wide. (Figure five times natural size.)

This little shell is found in great numbers in Pliocene deposits on both sides of San Francisco Bay—at Mission San José on the east, also near Stephen's Creek, and near Los Gatos on the west. *Carinifex newberryi* and other living species occur with it in localities, also some species that may, like this, be extinct. It differs from the *A. longinqua* Gould (found lately living at Lake Pt., Utah), in the tabulated whorls. Mr. Watts obtained specimens taken from an artesian well at Lambertson's, Tulare Co., 1,058 feet deep, with *Sphaerium dentatum* Hald., a species still living east of the Sierra Nevada.

FOSSILS DESCRIBED BY OTHERS, NOT FIGURED BEFORE, ETC.

Pinna alamedensis Yates. (Pl. IV, Fig. 53.)

[Report of the State Mineralogist of Calif. for 1887, p. 259.]

This species has nine concentric inequidistant rounded wrinkles emanating from the open side, and turning toward the hinge at nearly right angles, the entire shell marked by longitudinal narrow ribs (about forty), which, radiating from apex, extend to the basal margin, becoming more indistinct as they approach the lower margin. These ribs, at their intersection with the lines of growth, are ornamented by slight elevations, forming zigzag markings along the lines of growth. The hinge side is straight the entire length, the opposite side running parallel for about one half the distance from base to apex, where it makes a sharp curve, thence at an angle of about forty-five degrees to the apex. Length 9, width 5, and thickness about 2 inches. Locality, Alameda Creek, Alameda County. Only one specimen found, and that a very fine one, in the center of a round sandstone bowlder. Miocene.

The above is the original description. Specimens have also been found by Dr. Bowers, in Ventura County, and the one here figured was found by Mr. Watts, in Kern County. It retains more of the shell than usually found, most of the specimens being casts.

Pinna venturensis Yates. (Pl. V, Fig. 54.)

[Report of the State Mineralogist of Calif. for 1887, p. 259.]

From the hinge side about two thirds of the width of this shell is marked by nine well-developed, narrow ribs, radiating from the apex to the basal margin; the other portion shows rounded, concentric inequidistant ribs, extending only to the line of the radiating ribs, so that about two thirds of the surface is covered by the radiating smaller ribs, and one third by the curved, concentric, rounded ribs or wrinkles, very like *Pinna pectinata*, figured in "Brown's Recent Conchology." *Pinna venturensis* is short and thick compared with its length. The largest specimen found was about five and one half inches long, three and one half in width, and one and three fourths in thickness, the hinge side considerably shorter than the other. Locality, several specimens collected by the writer in Casitas Pass, Ventura County. Pliocene.—L. G. Yates.

This is the original description, and photographs of both the species kindly furnished by Dr. Yates, show that those here figured represent his species. All seen of this species only show the internal cast of the shell, and, as in living species, the external sculpture may have been quite different. There is also but little to distinguish it from the Cretaceous *P. breweri* Gabb.

Pecten discus Conrad. (Pl. V, Figs. 55, 56.)

The original description and figure having been from a cast "beautifully preserved in indurated clay" (which is a very unreliable kind of specimen to describe, especially in this genus), I have here given figures from shells found by Mr. Watts in Kern County. This is about ninety miles northeast of the locality of its discovery, but the species found at the two places are to a great extent the same. The present specimens differ from the original type in having about three more ribs, in which they are intermediate between that and *P. deserti* Con. (of which Mr. Fairbanks also brought many good specimens from the Carrizo Creek locality). Clay casts, like the original, are common in Ventura County, and were collected by Dr. Bowers, but none with shell remaining were found there. It seems likely that the species named will have to be combined as one, the differences being within the range of variation in many other species. The internal view of the larger valve was necessary, because it is so incrusted on the outside with hard rock that it cannot be separated without probable fracture. The small one is about equally convex on both sides, as in *P. deserti.* The original type very much resembled the convex valve of *Vola bella* Con.

Liropecten estrellanus Conrad. (Pl. V, Figs. 65, 67.)

Pallium estrellanum Con., Pacif. R. R. Rept., vol. VI, 1850, p. 71, pl. 3, fig. 15. Vol. VII, p. 191, pl. 3, figs. 3, 4.

P. crassicardo Con., Proc. Phil. Acad. Nat. Sc., Dec. 1862, p. 291.

Spondylus estrellanus Con., Pac. R. R. Rept., vol. VII, p. 191, pl. 1, fig. 3.

Liropecten estrellanus Con., *L. crassicardo* Con., *L. volæformis* Con., Proc. Phil. Acad. Nat. Sc., 1862, p. 291.

Pecten pabloensis? Con., Pac. R. R. Rept., VI, p. 71, pl. 3, f. 14.

Specimens were collected by all the assistants in the Coast and San Joaquin Valley counties, from Solano to Orange Counties; also by Mr. Lockwood, in Napa County, etc., showing every variation.

Although Mr. Gabb admitted all four of Conrad's supposed species here named, I am satisfied from much more and better materials than he had, that they only represent various ages and conditions of only one, or possibly two, if *Pecten pabloensis* can be maintained; if not it will have priority as the specific name. The specimen figured shows nearly all the characters of the various forms combined, admitting that *P. pabloensis* is only the young stage. The ribs vary from sixteen to nineteen, though given as seventeen in all except the last by Conrad, who gives them as eighteen to twenty in that. The intermediate riblets are at first one in each space, but between the six anterior ribs on the lower (right) valve and nine on the upper, they increase, as the shell grows, to four and six, the two latter being on the sides of the ribs.

When still larger the whole of the ribs and interspaces are covered with riblets, as in *P. subnodosus* (*Liropecten veatchii* Gabb), and many others. Conrad's supposition that "*L. volæformis*" must have one flat valve, i only based on the fact that his convex valve was unusually convex, as often found in this species, while the transverse lines on the ribs are also found where the shells grew too crowded. His "*L. crassicardo*" was an old specimen, having more riblets and a stronger hinge, and really represents the left valve of the species. In the one figured here there is scarcely any difference in the convexity of the two valves, but it is rarely found with both together, and sometimes they occur unequal or both much flatter, which often arises from pressure since fossilization. The distinctive characters of *Liropecten* are in the strongly-toothed hinge, approaching that of *Spondylus*, and this was finally admitted by Conrad as a character common to them all, when he included them in that new genus. The great convexity of the valves in two of his "species" is due to what he calls "undulation," but is a kind of imbrication, as shown in the figure. It is not a natural character, being never twice alike, but seems to have been caused by some unfavorable condition of growth. It is sometimes seen in living species, and on the other hand fossil *Liropectens* sometimes grew without it, as shown in his figure of *L. crassicardo.*

The pair of valves is well represented just as it was found; the ears are from another specimen, which is of the original estrellanus form. Found in Coast Range Tertiary from Oregon to Santa Rosa Island, Calif., but not farther southward.

Note.—In the Catalogue of Californian Fossils, published in the Seventh Annual Report of State Mineralogist, 1887, p. 246, the form *Liropecten volæformis* Con. is given as living on west coast of Mexico, and probably the same as *L. subnodosus* Sowerby, 1835. This reference was intended for *L. veatchii* Gabb, but was accidentally misplaced.

FOSSILS FROM COLORADO DESERT, COLLECTED BY H. W. FAIRBANKS

These were collected only near Carrizo Creek where it emerges from the mountains forming the western rim of the desert, and are of more than usual interest. Many collectors have been to the same locality and obtained the Tertiary species described by Conrad thirty-six years ago, as well as the Quaternary fresh-water shells of the recent lake-bed, most of which still live elsewhere. Loose species of fossiliferous rock of Carboniferous age are also found, but none in place, in that vicinity. The chief interest of Mr. Fairbanks' collection is the discovery of what may be called fossil coral-islands, the coral forming extensive beds about the summits of short isolated ridges detached from the mountains of the western rim, and consisting at their bases of granitic or metamorphic rocks. The ridges appear to have been islands when the desert formed part of the Gulf of California, or of the Pacific Ocean, and were at the right depth beneath the surface for coral growth on their summits for a long period. With the coral occurred several fossil shells of forms quite unlike those of the late Tertiary of Carrizo Creek beds, and apparently unlike those now inhabiting the Gulf of California. They are not perfect enough for description, but may be identified with some, of which the age is known, from farther east, and for that purpose have been sent to the U. S. Nat. Museum, where eastern species are preserved. They certainly do not resemble any of the fossils yet described either from the Cretaceous or Tertiary beds of California, and suggest that they lived in the period of which fossils are wanting west of the Sierras, namely, the Eocene, or its later divisions following the Cretaceous B deposits. There is an absence of anything characterizing the secondary period. The shells resemble species of Cytherea, Dosinia, Axinæa, Pyrula, and Tritonium of large size; also an oyster, thicker and heavier than the living, or Pliocene fossil species, approaching *O. titan*, but strongly ribbed on upper valve. It is near *O. herrmanni* Conrad, but seems distinct. Further collections from such coral-islands, of which there may be many in the desert, will prove very important in unfolding the geological history of the region, but the want of water and feed for horses makes it very difficult to explore them, unless it is done in the winter. Dr. E. S. Clark, who is familiar with the fossil corals of the Eastern States, informs me that the species found by Mr. Fairbanks cannot decide the age of their growth, being widely spread in Mesozoic and Tertiary formations.

By late letters from Dr. White it appears that the specimens mentioned above as sent for identification cannot be confidently named as being any contained in the U. S. Nat. Museum.

CATALOGUE OF CRETACEOUS (AND EOCENE?) FOSSILS OF SAN DIEGO COUNTY.

Chiefly Collected by Mr. H. W. Fairbanks.

	Before Classed with "Div. B." or Eocene.	Before Classed with "Cretaceous Div. A."	West Base of Pt. Loma.	Near La Jolla.	Near False Bay.	Rose Cañon.	Cooper's Collection.	Near Soledad.	Near Kelly's.	Near San Luis Rey.	Remarks. For localities elsewhere see Catal. of Fossils in Report of the State Mineralogist for 1887.
	B	A	A	A	B	B	B	B	B	B	
Actæonina pupoides Gabb		*	*								
Ammonites hoffmani? Gabb		*	*	*							
whitneyi Gabb		*	*								
Ampullina striata Gabb		*	*								
Ancillaria elongata Gabb	*				*		*				
Angaria ornatissima Gabb		*	*								
Arca breweriana Gabb		*	*			*			*		
Architectonica horni Gabb	*				*						
Astarte mathewsoni Gabb		*	*								
semidentata J.G.C.						*					
Avicula pellucida Gabb	*	*			*						
Axinæa sagittata Gabb	*					*					S. D. specimens probably all this sp.
veatchii Gabb	*?	*	*	*			*?				
Baculites chicoensis Trask		*	*	*			*				
Barbatia morsei Gabb	*						*			*?	Found by Mr. E. W. Morse.
Bulla assimilata J. G. C.					*						
Calliostoma kempiana J.G.C.			*								
Cardita planicosta Lamk.	*				*	*		*			Merced Falls, Watts; Oregon, (White).
Cardium cooperi Gabb	*				*	*	*				
placerense Gabb		*	*								
Caryatis nitida Gabb		*				*					
Cerithiopsis alternata Gabb	*					*					
Cerithium pillingi? White		*									Ensenada, Lower Cal.
fairbanksi J.G.C.			*								
Chione varians Gabb		*	*	*							
angulata Gabb		*							*		
Cinulia obliqua Gabb		*	*	*							
Conus horni Gabb	*				*						
remondi Gabb	*				*		*				
Coralliochama orcutti W'te		*	*	*							Ensenada, Lower Cal.

Cretaceous (and Eocene?) Fossils of San Diego County—Continued.

	Before Classed with "Div. B," or Eocene.	Before Classed with "Cretaceous Div. A."	West Base of Pt. Loma.	Near La Jolla.	Near False Bay.	Rose Cañon.	Cooper's Collection.	Near Soledad.	Near Kelley's.	Near San Luis Rey.	REMARKS. For localities elsewhere, see Catal. of Fossils in Report of the State Mineralogist for 1887.
	B	A	A	A	B	B	B	B	B	B	
Corbula parilis Gabb	*				*	*	*				
triangulata J.G.C.			*								
Crassatella tuscana Gabb		*	*								*Astarte tuscana* Gabb.
uvasana Gabb	*				*	*		*	*		
lomana J. G. C.			*								
Crenella santana J. G. C.			*								
Cylichna costata Gabb	*	*	*		*	*		*	*		
Dentalium cooperi Gabb	*	*			*		*				
stramineum G'b	*	*	*			*	*				
Dosinia elevata Gabb	*							*			
gyrata Gabb	*				*	*	*				
Euspira alveata Gabb	*	*					*				
Fasciolaria læviuscula G'b	*	*					*				
sinuata Gabb	*						*				
Ficopsis cooperi Gabb							*				
remondi Gabb	*				*	*		*			
Fusus diaboli Gabb	*				*	*					
tumidus Gabb		*	*			*					
martinez Gabb	*						*				
supraplanus J. G. C.					*	*					
Galerus excentricus Gabb	*				*	*	*			*	Omitted in Catal.
Goniomya borealis? Meek			*								
Gryphœa vesicularis Lamk.		*	*	*			*			*?	
Hamites vancouverensis Meek		*	*	*							Var. **fremonti** Marcou.
Helcion dichotomus Gabb		*	*								
Heteroceras cooperi Gabb		*	*								
Inoceramus vancouverensis Shum.		*	*	*							*I. ellioti* Gabb and *I. whitneyi* Gabb. Very large.
Leda gabbi Con.	*		*		*						
Lima appressa Gabb		*	*								
microtis Gabb		*	*								
Lithophagus oviformis G'bb		*	*								
Litorina compacta Gabb	*	*			*		*				Omitted in Catal.
Loxotrema turrita Gabb	*							*			
Lucina postradiata Gabb		*	*								Pal. of Cal., vol. II, p. 189.

CRETACEOUS (AND EOCENE ?) FOSSILS OF SAN DIEGO COUNTY—Continued.

	Before Classed with "Div. B," or Eocene. B	Before Classed with "Cretaceous Div. A." A	West Base of Pt. Loma. A	Near La Jolla. A	Near False Bay. B	Rose Cañon. B	Cooper's Collection. B	Near Soledad. B	Near Kelley's. B	Near San Luis Rey. B	REMARKS. For localities elsewhere, see Catal. of Fossils in Report of the State Mineralogist for 1887.
Lunatia (Gyrodes) conradiana Gabb		*	*								Omitted in Catal.
Lunatia horni Gabb	*							*			
Lunatia nuciformis Gabb	*						*?				
Margaritella crenulata G'b	*	*					*				
globosa Gabb		*			*?						
Megistostoma striatum G'b	*							*			
Megerlia? dubitanda J.G.C.			*	*							
Meretrix arata Gabb		*	*								
horni Gabb	*				*	*		*			
uvasana Con.	*				*			*			
Mitra simplicissima J.G.C.						*					
Morio tuberculatus Gabb	*				*	*	*				
Mytilus ascia Gabb	*			*							
pauperculus Gabb		*	*						*		
quadratus Gabb		*	*	*							
Naticina obliqua Gabb	*					*		*			
Neptunea cretacea Gabb	*							*			
supraplicata G'b	*						*				
Nerita triangulata Gabb	*							*			
Neverita globosa Gabb	*				*	*					
secta Gabb	*		*			*					
Nucula truncata Gabb	*	*	*			*					
Olivella mathewsoni Gabb	*				*	*		*			
Ostrea idriaensis Gabb	*							*		*	
Patella traskii Gabb		*	*								
Pecten californicus Con.		*	*								
traskii Gabb		*	*	*							
N. Sp?			*	*							Perhaps a *Spondylus.*
Perissolax blakei Gabb	*					*		*			
brevirostris G'b		*	*								"Intermediate strata" Gabb.
Pholadomya breweri Gabb		*	*								
Placunanomia inornata G'b										*	Omitted in Catal.
Pleurotoma fairbanksi J. G. C.						*					
Rimella simplex Gabb	*						*				

Cretaceous (and Eocene?) Fossils of San Diego County—Continued.

	Before Classed with "Div. B," or Eocene.	Before Classed with "Cretaceous Div. A."	West Base of Pt. Loma.	Near La Jolla.	Near False Bay.	Rose Cañon.	Cooper's Collection.	Near Soledad.	Near Kelly's.	Near San Luis Rey.	Remarks. For localities elsewhere see Catal. of Fossils in Report of the State Mineralogist for 1887.
	B	A	A	A	B	B	B	B	B	B	
Septifer dichotomus Gabb	*			*							
Siphonaria capuloides J. G. C.			*								
Solen diegoensis Gabb	*		*	*	*	*					
parallelus Gabb	*			*							
Stomatia intermedia J. G. C.			*	*							
Surcula preattenuata Gabb						*					
Tapes quadrata Gabb	*		*								
Tellina æqualis Gabb		*	*		*				*		
ashburneri Gabb		*			*						
decurtata Gabb		*	*								
horni Gabb	*				*						
longa Gabb	*									*	
ovoides Gabb		*	*							*	
whitneyi? Gabb			*	*							
Tornatella normalis J. G. C.			*								
Tornatina erratica J. G. C.						*					
Tritonium californicum G'b	*							*			
diegoensis Gabb	*						*				
whitneyi Gabb	*	*					*				
Trapezium carinatum Gabb		*									
Turritella chicoensis Gabb		*			*	*			*		
uvasana Gabb	*					*		*			"Cret." in Catal. by error.
Urosyca caudata Gabb		*	*								
Venus æquilateralis Gabb	*				*			*		*?	
Waldheimia? imbricata J. G. C.				*							

EXPLANATION OF PLATES.

Plate	Figure	**A** and **B**, Div. of Cret. **M B**, Marysville Buttes. **C M**, Coal Mines. **D**, San Diego. Other localities (in table). **T**, Tertiary. **M**, Miocene. **P**, Pliocene. **K**, Kern County.	Formation and Locality			
			Cret.		Tert.	
			A	B	M	P
1	1	*Terebra wattsiana.* Part of anterior whorl is broken off		M B		
	2–4	*Surcula crenatospira.* Fine sculpture not represented		M B		
	5	*Narona irelaniana.* Half of anterior whorl broken off		M B		
	6–11	*Ancilla (Oliverato) californica.* In Fig. 7 the anterior face of shell is much worn, showing the edges of incrusting layers		M B		
	12	*Cerithium fairbanksi.* Very little of the external surface remains to show details of sculpture	D			
	13	*Potamides? davisiana.* Most of aperture wanting		M B		
	14–19	*Cerithidea carbonicola.* The variations of sculpture in the six examples are not wholly represented		C M		
2		*The figures 20 to 30 in Pl. 2 are double the natural size.*				
	20–21	*Surcula inconstans.* Varieties described in text		M B		
	22	*Cordiera gracillima.* Plications are not well figured		M B		
	23–24	*Pleurotoma perkinsiana.* Figures too wide		M B		
	25–26	*Mangilia suturalis.* The nodules too prominent		M B		
	27	*Drillia ullreyana.* Outline not very correct		M B		
	28–29	*Surcula monilifera*		M B		
	30	*Bittium longissimum.* See description for details of form		M B		
	31	*Fusus supraplanus.* Apical whorls from mould	D			
	32	*Pleurotoma? decipiens*	D			
	33–34	*Calliostoma kempiana.* The last shows basal surface				
	35	*Tornatina? erratica*	D			
	36–37	*Tornatella normalis.* Shows variations in width	D			
	38–39	*Siphonaria capuloides.* Both from one specimen	D			
	40	*Crenella santana.* Also in Orange County. (Bowers.)	D			
	41	*Mitra simplicissima.* Similar to *M. simplex*	D			
	42	*Corbula triangulata.* The oblique lines on the anterior end were intended for shading	D			
3		*The figures are all of natural size from 43 to 60.*				
	43	*Stomatia intermedia.* Details of sculpture, compiled from three specimens	D			
	44–45	*Astarte semidentata.* Umbonal angle of 45 too narrow	D			
	46	*Bulla assimilata.* The spire is not prominent, the posterior angle of mouth being highest	D?			

Explanation of Plates—Continued.

Plate	Figure		Formation and Locality.			
			Cret.		Tert.	
			A	B	M	P
3	47	*Crassatella lomana.* For fine sculpture see description	D			
	48–49	*Megerlia dubitanda.* Upper and lower odd valves	D			
	50–51	*Waldheimia imbricata*	D			
	52	*Agasoma (Trophosycon) barkerianum.* Mouth imperfect				K
4	53	*Pinna alamedensis.* Yates' type was nearly twice as long as this, and complete in form				K
	54	*Pinna venturensis.* Three fourths the size of largest found, and with fewer ribs. Ventura County				
	55–56	*Pecten discus* Conrad. From the shells Lately received specimens from Tar Cañon, Kern County, on the W., have ears nearly perfect. They are nearly of the outline given by Conrad, and have about six delicate riblets radiating from the umbo, crossed by lines of growth. One valve was flatter, as in *P. latiauritus*, but that has 14-16 ribs.				K
5	57	*Planorbis pabloanus* The outlines are correct as copied from the fossils, but the surface restoration is a fancy of the engraver. Contra Costa County.				
	58	*Anodonta lignitica*				
	59	*Limnæa contracosta*				
	60	*Amnicola yatesiana.* Magnified five diameters				
	61–62	*Cucullæa bowersiana.* From Orange County				
	63	*Agasoma kernianum.* Very well represented				K
	64	*Mytilus dichotomus.* Umbonal end perfect when described, but broken before figuring		C M		
6	65–67	*Pecten (Liropecten) estrellanus* Conrad. From two specimens, to show the combination of characters assigned by Conrad to three species				

It should be stated that while the figures represent the best of each species, many points of the descriptions have been supplied from other specimens, that are not shown in the figures.

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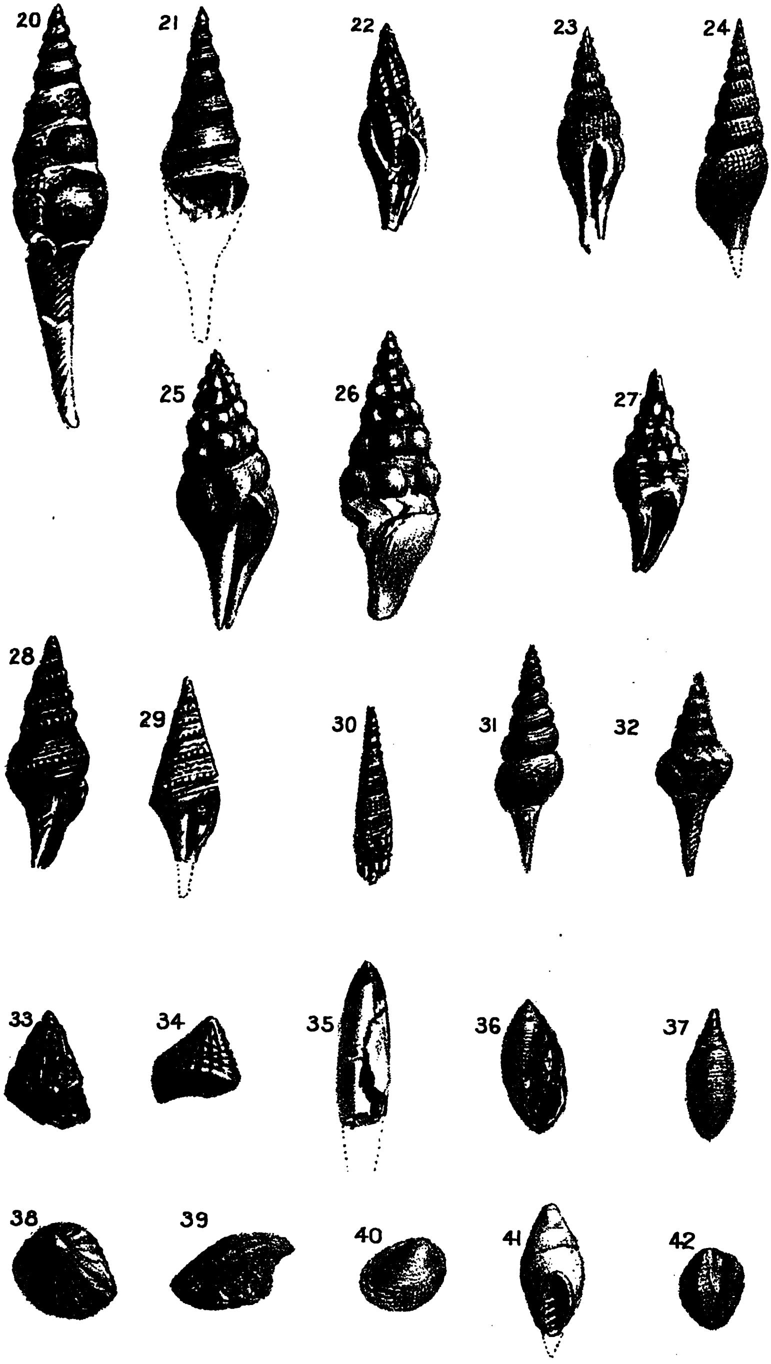
PLATE 2.



LITH. BRITTON & REY S.F.

PLATE 3.

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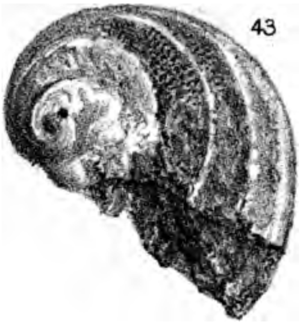
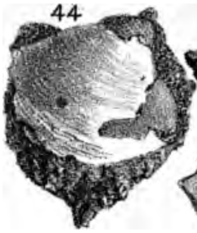


44



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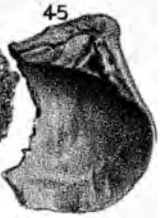

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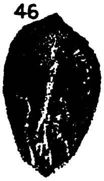

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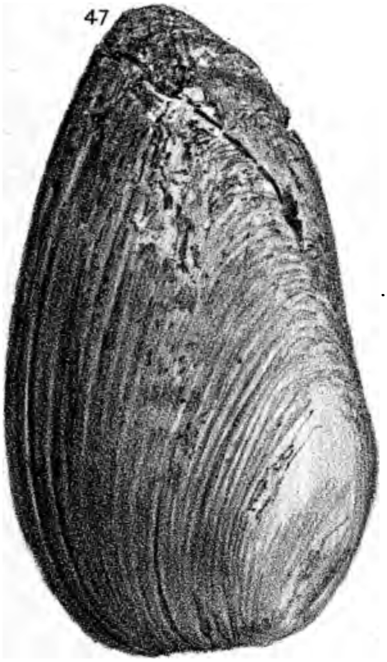

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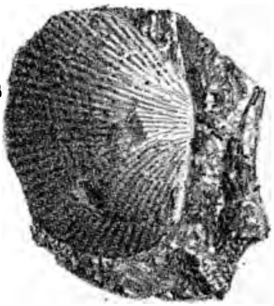

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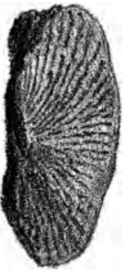

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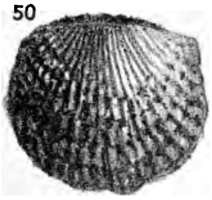

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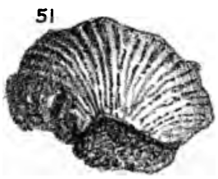

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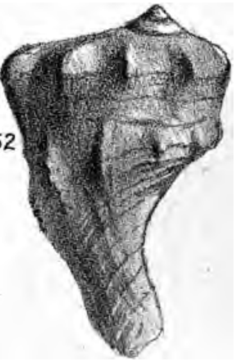

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PLATE 4.

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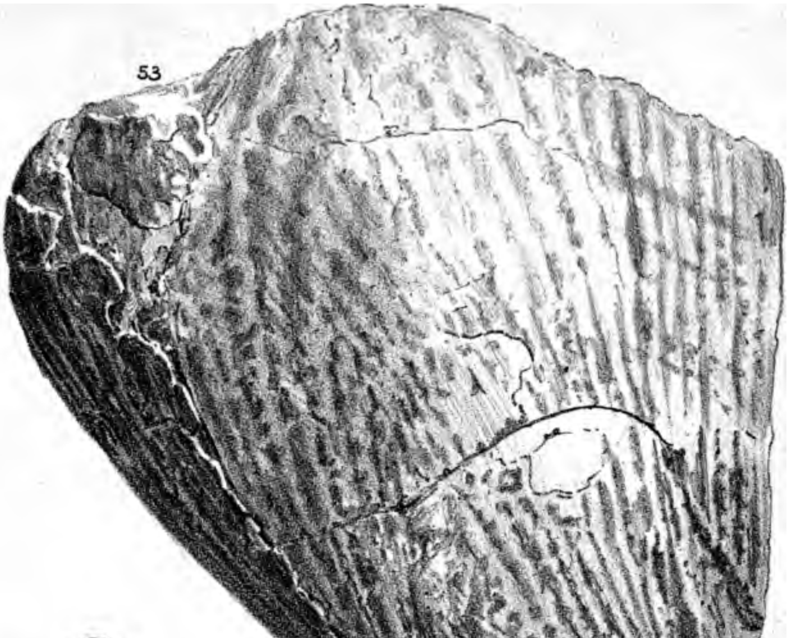

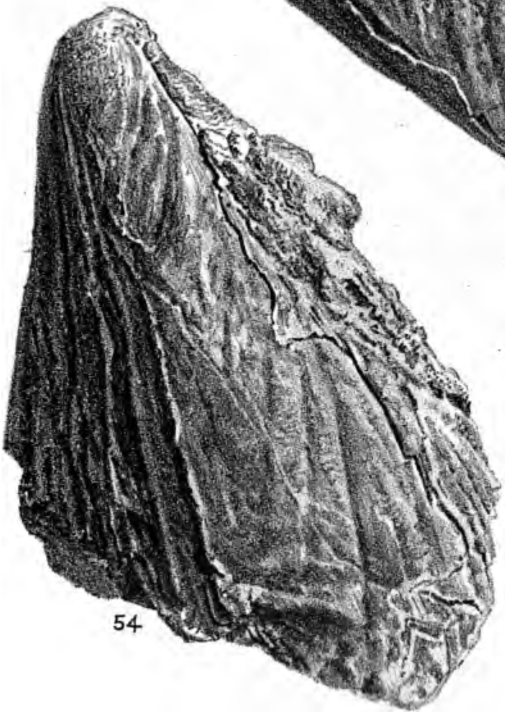

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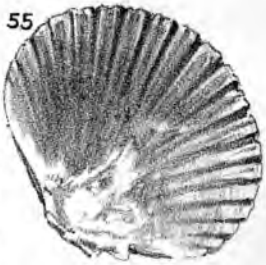

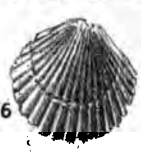

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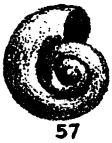
PLATE 5.



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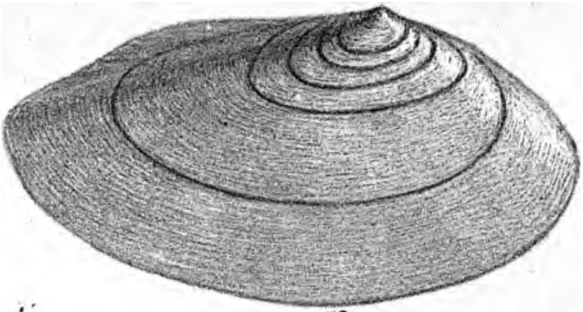

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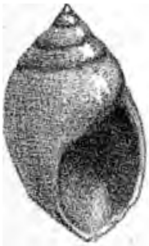

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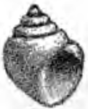

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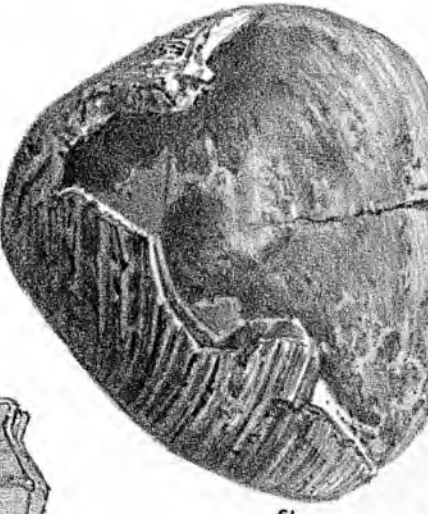

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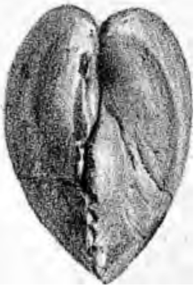

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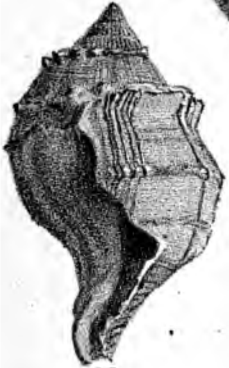

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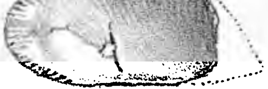

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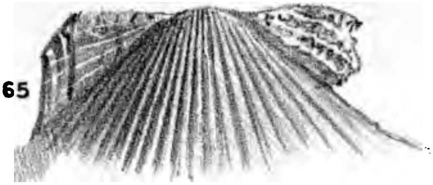

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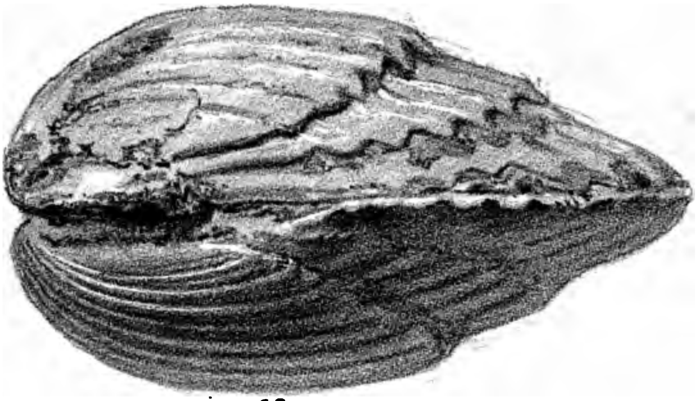

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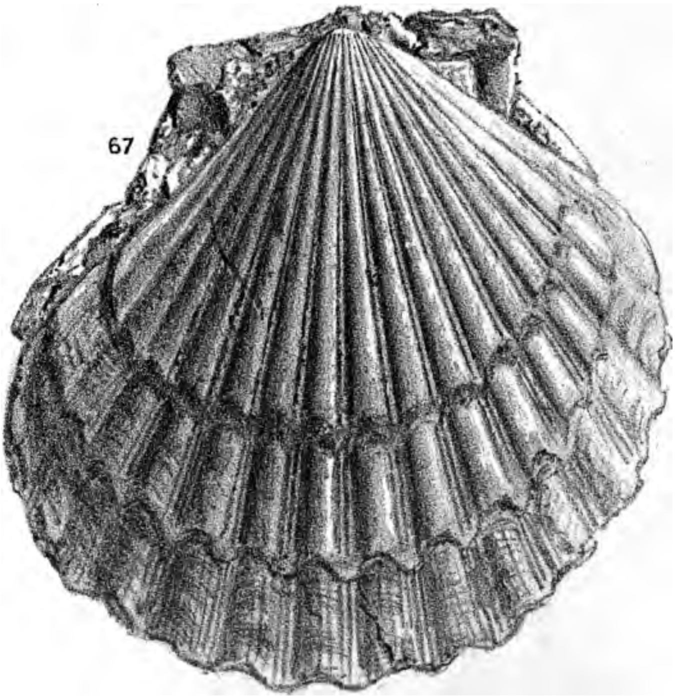

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